DRAINAGE FOR TEA

Edited By

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TEA RESEARCH ASSOCIATION

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FOREWORD

In 1968, Tocklai arranged for a special visit of Mr. P.A. Browne (U.K.), who studied the magnitude and nature of waterlogging in various tea growing regions and submitted a comprehensive report. Thereafter, in 1971, Mr. W.J. Grice, the then Chief Advisory Officer, Tocklai, prepared a Memorandum (No. 28) on catchment planning. These efforts proved to be very successful in bringing awareness among Tea Planters regarding the importance of drainage and possible ways to tackle it.

Various research experiments conducted by Tocklai Scientists since 1977, have added enormous information as regard to identification of drainage problems. Types of field investigations needed for drainage of flat lands, lands with rolling topography and steep hill slopes of Darjeeling under Tea plantation, have been identified. The criteria for planning, selection and design of drainage system for different agro-climatic regions of N.E. India, the design and installation of underground pipe drainage system for unstable soils and pump outlets for areas having restricted outlet is being developed.

It is estimated that about 1,00,000 hectares of land under tea will have to be provided with improved drainage system during the period 1985-90. It is expected to produce 25 million kg of additional crop valued at about 625 million rupees. The estimated cost involved would be only about Rs. 200 million. The cost-benefit ratio of drainage improvements, therefore, comes to about 1:3, making it very attractive, commercially. This also clearly justifies the attention that this major area (Drainage) deserves to be paid in tea gardens.

The issue of 'Drainage for Tea' has been framed in a way that it adequately covers all the necessary aspects of waterlogging and its management under different soil, climatic, topographic and hydrological conditions prevailing in tea producing regions of N.E. India.

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1

DIAGNOSIS AND INVESTIGATION OF DRAINAGE PROBLEMS

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DRAINAGE

Definition

Drainage is defined as the removal of excess water from the crop root zone. Field capacity of a given soil is the level at which the plants can withdraw water from the soil unrestrictedly to produce optimum crop. So the soil water in excess to field capacity can be considered as excess water. The amount of excess water present in the root zone is a direct measurement of the degree of waterlogging at that time but it is difficult to monitor in the real field situation.

There are several other ways to know whether a particular land needs drainage or not. They can be grouped as surface and sub-surface indications.

A. DIAGNOSIS OF DRAINAGE PROBLEMS

1. Surface indications of poor drainage

1.1 Poor growth and flush

Satisfactory growth cannot take place until a minimum soil temperature has been reached. Much heat is lost in evaporating the excess moisture and so a poorly drained soil will be slower to warm up than a well drained soil. Microbiological activity and root growth are greatly affected by the soil temperature. Microbiological activity is greatly restricted below a temperature of 10°C. Above 10°C the activity increased with a corresponding increase in the availability of nitrogen, phosphorus and sulfur, brought about by the decomposition of fresh organic matter which results in considerable increase in yield.

1.2 Patchy crop

Uneven crop growth and vacancy can often be the result of varying drainage conditions e.g. high ground water table at some places. It could also be due to variation in the nature of the soil resulting in surface water accumulation on the heavier soils.

1.3 Poor response to fertilisers

The full benefit of fertilizers cannot be obtained in poorly drained land. Root development and crop growth restricted by poor drainage lessens the response to fertilizers. Some patches will show high acidity symptoms as a result of washing out of calcium.

Waterlogging generally leads to a deceleration in the rate of the decomposition of organic matter, which means the organic matter accumulates after waterlogging. Because of the slowing down in the rate of decomposition, nitrogen tends to remain locked-up in the organic residues. Nitrogen therefore, is often a limiting factor to plant growth on poorly drained soils.

In drained soil, the mineralization of nitrogen, that is the release of nitrogen upon the decomposition of organic matter, proceeds at a steady state. In waterlogged soils, however, the rate of mineralization decreases rapidly after an initial period of rapid release.

Waterlogging has an effect on the uptake of nutrients by plants. This is shown by certain symptoms which develop under conditions of waterlogging. These symptoms may be yellowing, reddening, or a scorched or stippled appearance of the leaves.

1.4 Drought

Plants on poorly drained land form shallow rooting systems and consequently in dry period they are unable to obtain sufficient moisture to maintain full growth and they rapidly show drought symptoms. On the other hand, in well drained soils, the roots are encouraged to grow deeper which results in stronger plants able to withstand drought better and longer.

1.5 Crop diseases

Crop in poorly drained land has a tendency to attract more pests and diseases. Drainage influences the incidence of diseases and pests through its influence on soil conditions and plant growth. Infestation of Violet Root Rot, Black Rot, Blister Blight, Red Rust and shot hole borer in tea are some examples under waterlogged conditions.

1.6 Weeds

Shallow rooting, surface creeping types of grasses, and narrow leaved weeds thrive well under poor drainage conditions. Soils waterlogged for long periods become infested by sedges and rushes and where permanently saturated, the aquatic grasses predominate.

2. Sub-surface indications of poor drainage

Surface conditions will indicate that a problem exists. Sub-soil conditions will show whether or not this is due to poor drainage and if it is, will point towards its nature and cause. A pit, about 1.5 metre deep, is required to expose a vertical face or profile of the soil.

2.1 Soil colour

As a general rule, uniform brown or brownish shades throughout the depth of the profile suggest that there is no drainage problem. On the other hand dark grey, blue and blackish tones usually indicate that the soil is permanently waterlogged. Rust coloured mottling and occurrence of red, yellow and other colours at any level within the soil profile refers to the oxidation after a period of reduction under the region of a fluctuating water table and suggests that the soil was waterlogged at certain times of the season. The grey-greenish colours occur due to the reduction of ferric iron to ferrous iron.

Root development

In soils with good drainage and a well developed structure, the root ystem is able to develop to its fullest extent. On poorly structured wet ınds they will die back. A mass of fine roots at a shallow depth will indi- ate a barrier such as watertable, hard pan or structureless layer below.

.3 Soil structure

In a well drained soil, air and water are able to move freely through he cracks and fissures which are the features of a soil with good structure. Vhere the structure is poor, a drainage problem can arise. Examine the pro- ile for any compacted or structureless layers. For example, a hard pan, a ust-coloured iron pan, compaction due to continuous movement of labourers r machineries or a naturally structureless sub-soil.

.4 Ground water table

The water table is the upper surface of the saturated zone of free round water. Free ground water is defined as water neither confined by rtesian conditions nor subject to the forces of surface tension. At the water able, the water is under atmospheric pressure. Thus, the water table is the maginary surface separating capillary water from the free ground water elow. The presence of ground water in the profile pit will indicate the rainage problem. This should, however, be considered in conjunction with the vidence provided by the sub-soil.

DRAINAGE INVESTIGATIONS

Drainage projects require survey and investigation of site conditions and tudy of historical data to determine their feasibility and for design. The nvestigation for drainage work may be divided into three types:

1. Reconnaissance survey
2. Preliminary survey
3. Design survey

1 Reconnaissance

It is usually an inspection of the area from easily accessible points. 'his investigation helps in determining the drainage problem in the area and he principal improvements needed and to make a rough estimate of the ost.

1.1 Objectives

i) to determine type of improvements required, flood prevention, surface drainage and sub-surface drainage,

ii) to determine the adequacy of outlets for the needed improvements,

iii) to develop a general plan for improvement,

iv) to make an estimate of the cost and benefits of the proposed improvements.

3.1.2 Procedure to follow

i) assemble and evaluate existing data,

ii) prepare a work map of the project area showing boundaries of the watershed, existing streams, old ditches and drains,

iii) obtain or develop soil map and land use map of the project area,

iv) observe functioning of existing drains, bridges, topographic conditions and groundwater levels,

v) determine adequacy of outlets for drainage improvements,

vi) estimate cost-benefit of proposed improvements.

3.2 Preliminary survey

This is rather a comprehensive survey. Extensive field surveys and investigations are made, problems are located and remedial measures are planned and preliminary designs are made.

3.2.1 Objectives

i) specifically locate areas in need of improvement - flood protection, surface drainage, subsurface drainage,

ii) select design criteria,

iii) make preliminary design of all the principal features of planned improvements,

iv) prepare estimate of cost and material required.

3.2.2 Procedure to follow

i) evaluation of data collected during reconnaissance,

ii) prepare survey outlines with respect to the specific needs of the area.

3.3 Design survey

It is required for preparation of construction plans and specifications. Prior to construction of any drainage project, surveys and investigations should be made which show existing topography, structure, soil, ground water and hydrologic data.

3.3.1 Data required for design

i) soil maps and water table records in the problem area,

ii) piezometric contour maps to show seasonal changes,

iii) data on extent, frequency and seasonal flooding,

iv) adequacy of outlet,

v) land use pattern and proposed changes in cropping pattern

vi) topography of the problem area,

vi) select the location of all mains, laterals, interceptor drains, relief drains etc.,

vii) determine need for improvement in bridges, culverts, grade control structures, surface water inlets to pipe drains, sluice gates, pump outlet, and all other drainage structures.

4 Miscellaneous data

4.1 Data on flooding

It is important to determine if the area is subject to flooding. The loods may be so frequent and damaging that without their prevention, drainage of the project area would not be feasible. Points to consider here are:

(a) frequency of damaging floods,

(b) depth and duration of flooding;

(c) time of flooding,

(d) erósion and sedimentation caused by flood.

3.4.2 Data on adequacy of drainage outlet

In determining adequacy of outlets, the following basic requirements should be met:

(a) capacity of outlet according to drainage need of the area,

(b) possibility of easy discharge of subsurface flow,

(c) there should not be excessive scour or deposition of sediments in the outlet.

3.4.3 Data on economics of drainage project

In all cases, recommended improvements should provide benefits in excess of costs. Economic analysis is needed to make the feasibility determination.

3.5 Investigations for surface and sub-surface drainage

In some areas, the main problem will be surface drainage, and in other areas, subsurface drainage. The kind of investigations needed for surface and subsurface drainage are different and vary in different parts of the country.

3.5.1 Surface drainage

Surveys and investigations usually required for planning and design of surface drainage improvements are:

i) topographic surveys showing all features,
ii) soil surveys,
iii) land use,
iv) rainfall and runoff investigations,
v) high water level in drainage outlets,
vi) profiles and cross-section of existing drains,
vii) investigation on drain stability.

3.5.2 Sub-surface drainage

In addition to the investigations carried out for surface drainage system, information on soil, sub-soil, groundwater and perched water table, are needed for planning and designing of sub-surface drainage system.

Data on permeability, consumptive use, water table and surface topography are needed for drainage. Additional surveys and investigations required are:

i) logs of soil and subsoil,

ii) hydraulic conductivity measurements,

iii) position of water table in relation to ground surface,

iv) fluctuations in water table levels.

4 Types of drainage problems

Drainage problems differ widely because of the varied nature of physical conditions. The topography, soils and source of water of any given area vary so greatly that it requires a complete and thorough evaluation of these factors.

Successful drainage of wet area depends on a correct diagnosis of the problem. The typical drainage problems are:

4.1 Surface-drainage problems

Surface drainage is defined as the orderly removal of excess water from the surface of land by means of improved channels.

(a) Causes of ponding

i) Uneven land surface which restricts natural runoff,

ii) less permeable subsoil,

iii) undersized drains which fail to remove runoff water efficiently,

iv) poor outlet conditions which hold the water surface above ground level,

v) insufficient land slope to permit water flow on surface.

(b) Sources of surface water

1) Rainfall

2) Runoff from adjoining higher lands

3) Seepage from adjoining higher lands

4) Overflow from steams/rivers etc.

(c) Possible solutions

i) improve surface drains,

ii) land grading and smoothing,

iii) improved outlet,

iv) provide levees with culverts and flap gates,

v) install drainage pumps, if required,

vi) divert the source of water causing surface drainage **problem** if it is outside the project area.

.2 Sub surface drainage problems

i) Sub-soil poorly permeable;

ii) seepage from high lands;

iii) presence of springs or artesian at shallow depths **below ground.**

Important types of sub-surface drainage problems

1.2.1 Basin type free water table (Fig. 1.1)

In valley bottoms, the drainage problem is caused by free groundwater. Typically, the water table slopes gently down the valley. This large, very slowly moving body of ground water is fed by springs, surface **streams,** infiltration of rainfall water and surface runoff. The height of water table fluctuates with the seasonal variation of inflow of ground water. The general slope of the water table varies only slightly in response to the changes in inflow.

Possible solutions

Relief drains may be used to lower the water table in such areas unless soil permeability is too low. In sush lands, interception drains are not effective since the ground water slope is almost flat and the pervious sediments are too deep. However, the interception drains may be helpful if installed near the base of the hill. Where economically feasible, pumped-drainage wells are used to lower the basin type water table.

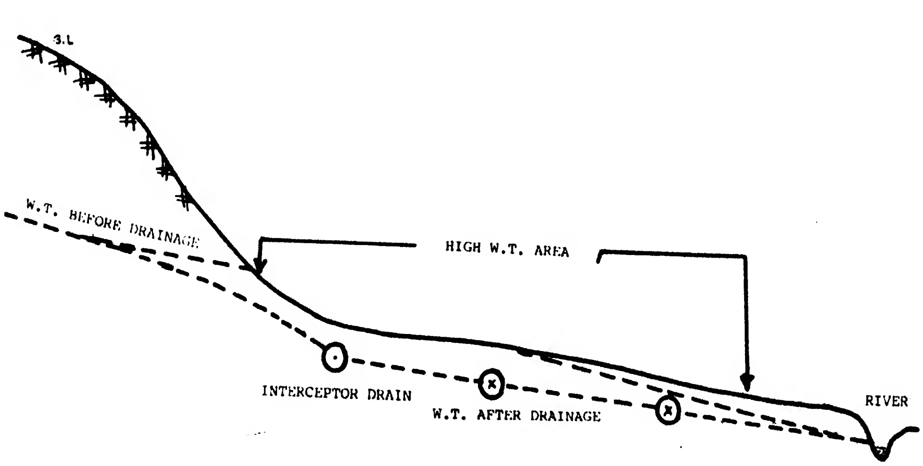


FIG. 1.1. DRAINAGE OF BASIN TYPE FREE WATER TABLE

4.2.2 Water table over an artesian aquifer (Fig. 1.2)

Groundwater may be confined in an aquifer so that its pressure surface is higher than the adjacent water table level. Such ground water is termed

Artesian. Leaks or weak points in the confined layer create an upward flo with hydraulic head decreasing in the upward direction. The groundwate moves in response to this hydraulic gradient and comes out as seepage a the ground surface or it escapes laterally through other aquifers above th confining layer.

Possible solutions

A water table supported by artesian pressure usually is more difficul to lower and maintain at the desired depth because it is difficult to contro water at the source. Such areas require:

i) relatively deep and closely spaced relief drains along with some interception drains to collect lateral flow,

ii) relief wells,

iii) pumped drainage wells that tap the aquifer.

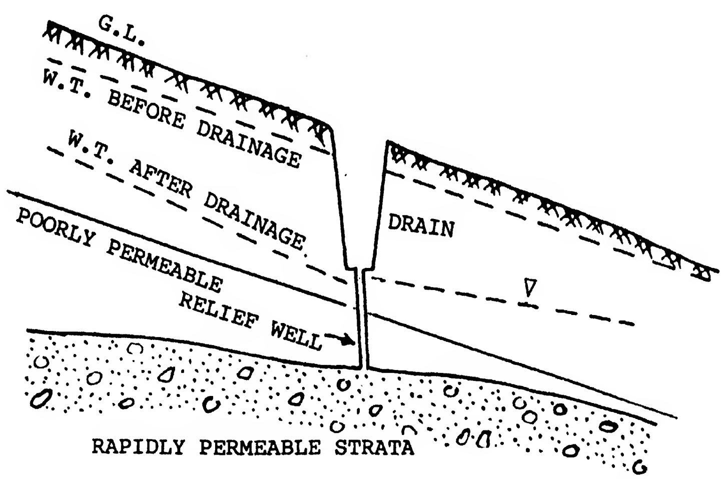


FIG. 1.2 DRAINAGE OF WATER TABLE OVER AN ARTESIAN AQUIFER

4.2.3 Perched water table problems (Fig.1.3)

Cause

In stratified soil, a subsurface drainage problem may be caused where excess water in the root zone is held up by a layer of low permeability. This may occur when surface sources build-up a local water table over the slowly permeable layer. Lateral percolation is too slow to drain the perched water naturally.

Solution

For the control of perched water table, the relief drains prove to be quite effective. In addition, an interception drain may be required to cut-off lateral seepage into the wet area. Theoretically, perched water could be drained downward by drilling wells (vertical drains) through the restrictive layer, if economical. Perched water tables may be controlled:

i) by reducing seepage from high lands,
ii) by providing surface drainage.

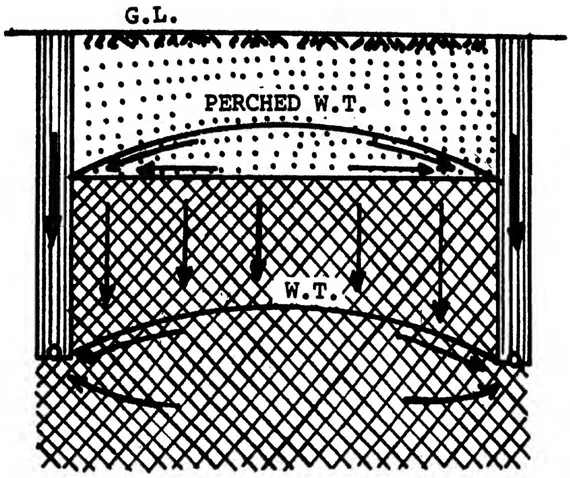


FIG. 1.3 (A) PERCHED W.T. PROBLEM IN PERVIOUS SOIL OVERLYING POORLY PERMEABLE SOIL

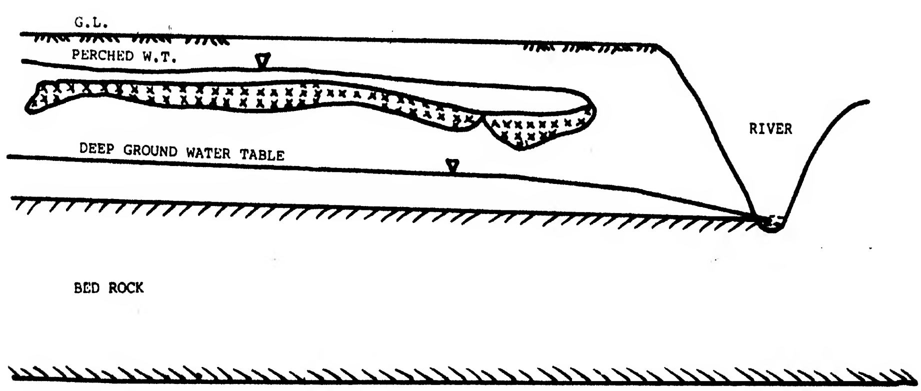


FIG. 1.3(B) DRAINAGE OF PERCHED WATER TABLE PROBLEM

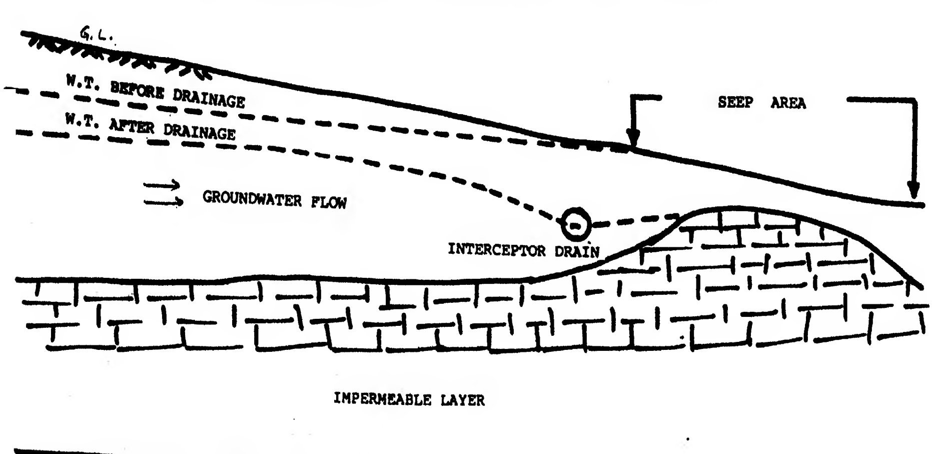


FIG. 1.4 DRAINAGE OF LATERAL FLOW (USDA, CSC, NO 16)

4.2.4 Lateral ground water flow problems (Fig. 1.4)

The problems of subsurface drainage may also be caused by horizonta movement of ground water in the crop rootzone. The flow pattern is influenced by soil stratification.

Soil layers often have permeabilities that differ a hundred or even a thousand fold. The velocity of flow of water in the soil varies directly with the permeability. Due to this reason, all significant flow may be limited to the more permeable layers causing subsurface drainage problem.

Solution

The drainage system which will be suitable for the removal of latera flow and location of drains will depend on the depth and orientation of the soil strata. For example, hillside seepage may appear where groundwater moves laterally over bedrock or over a layer of fine sediments to a point where it emerges out at the surface. In such a situation, one or more intercepting drains may be used to cutoff the flow which otherwise would reach the rootzone. Interception drains are effective where the aquifier is close enough to the surface so that it is feasible to cutoff the flow. Where interception drains are not practical, relief wells or pumped drâinage wells may be used.

4.3 Drainage of flat lands (Fig. 1.5)

Source of excess water

i) local rainfall,
ii) runoff from surrounding high lands,
iii) subsurface seepage or groundwater inflow.

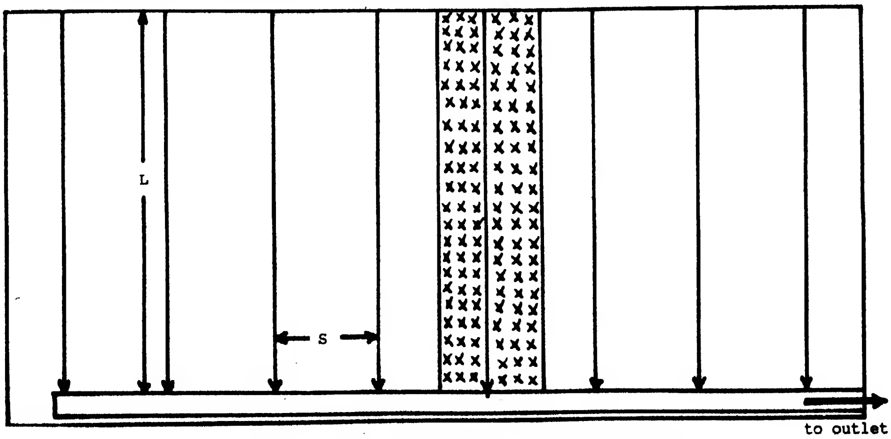


FIG. 1.5. DRAINAGE OF FLAT LANDS

Relief well - A shallow well, which carries water under hydrostatic pressure upward from a subsurface layer into a drain.

Pumped drainage well - A well sunk into an aquifer from which water is pumped to lower the prevailing water table.

Solution

Flat areas usually require a network of deep open or pipe drains and system of submain drains into which the laterals can discharge. The water from submain drains must be discharged into a main drain. The main drain will transport it to the outlet of the area.

In flood-prone areas, the submain drains can be connected to main drain by means of culverts with automatic gates or valves that close during floods.

Drain alignment should be such that the water is carried to the outlet by the shortest possible route.

.4 Drainage of sloping lands (Fig. 1.6)

The area having slope more than 3% are normally considered as sloping lands. In some cases, the land slope may even exceed 100%.

Source of excess water

i) foreign groundwater inflowing from adjacent upslope lands,

ii) springwater.

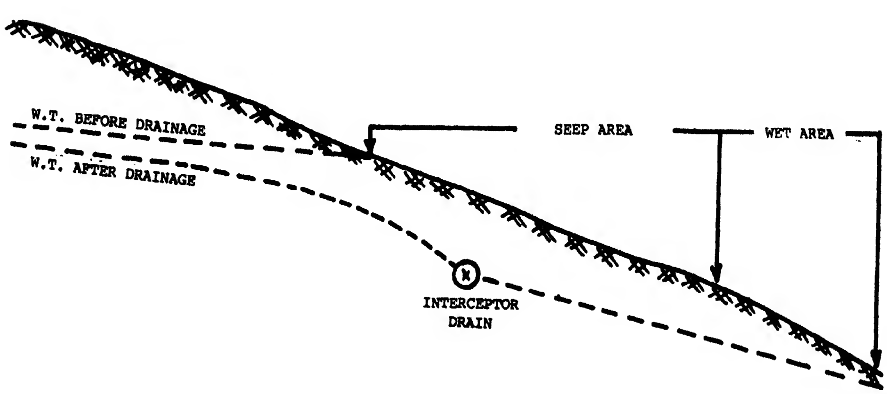


FIG. 1.6. DRAINAGE OF SLOPING LAND

Solution

In the drainage of sloping lands, it should be remembered that the excess water causing drainage problem may originate from different sources outside the problem area.

- The inflow of foreign groundwater from upslope may be checked by interception drains. These drains can be dug at one or more appropriate locations depending on the topography and geo-hydrological conditions of the area.
- If the drainage problem is caused by local water, the solution consists of a network of equally spaced drains of herringbone system. The laterals run parallel to the contour lines of the land surface and the main drains down the slope.

4.4.1 Investigations required

The geohydrological situation of areas where the inflow of foreign groundwater occurs is often rather complicated. This demands for careful field investigations such as:

i) determination of nature and direction of the groundwater flow,

ii) determination of the thickness, slope and hydraulic conductivity of the water-bearing strata.

Piezometers should be installed to measure the hydraulic head. These readings can be used to prepare the water table contour maps and hydraulic head difference maps. This information will reveal the location of the water-bearing strata.

Use of the geo-electrical methods will indicate the most suitable sites for the installation of interception drains. These drains should be located perpendicular to the direction of groundwater flow and should be deep enough to cut-off the lateral flow from upslope as much as possible.

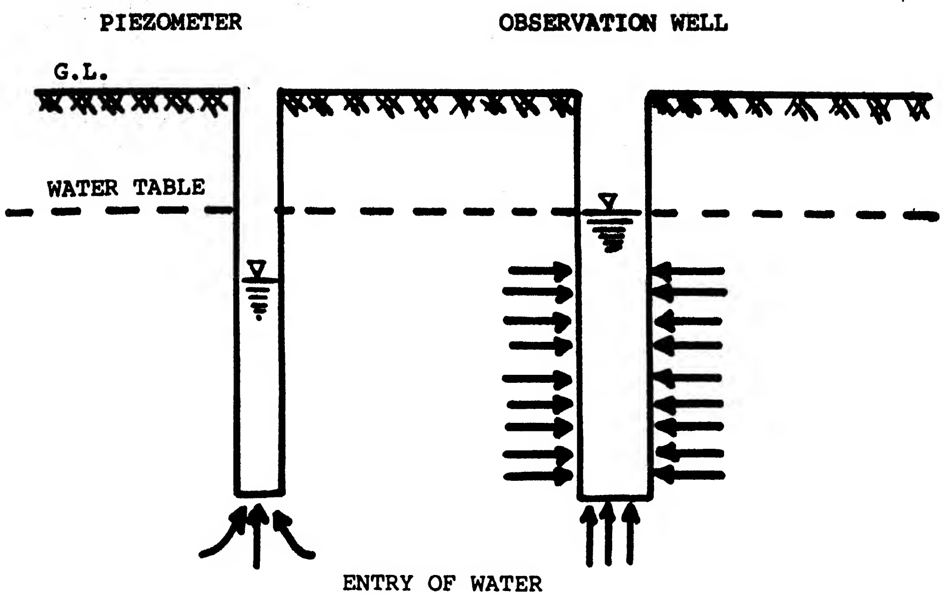
Groundwater investigations

Purpose

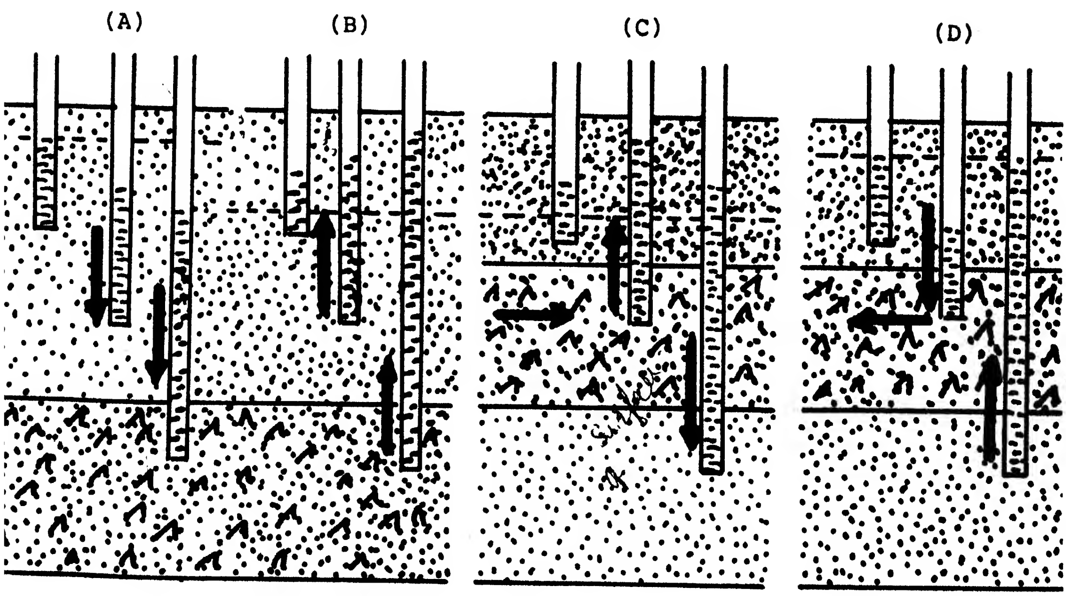
1) to provide information on position and fluctuations of W.T. at various points in the problem area,
2) to identify the areas of high W.T. and areas with acute drainage problem,
3) to determine the extent and severity of the drainage problem over the area,
4) to identify and locate the source of excess water,
5) to know the type of drainage system needed,
6) to know the suitable locations for subsurface drains.

Solutions

Install observation wells and/or piezometers to obtain required information on W.T. and hydraulic head, Fig. 1.7.



(A) PIEZOMETER INDICATES SOIL WATER PRESSURE
(B) OBSERVATION WELL INDICATES WATER TABLE



(A) GROUNDWATER MOVING DOWNWARD
(B) GROUNDWATER MOVING UP FROM A DEEPER LAYER
(C) HYDROSTATIC PRESSURE IN A STRATUM FORCING WATER UP & DOWN
(D) WATER MOVING INTO A STRATUM & GOING OUT AS HORIZONTAL FLOW

FIG. 1.7. USE OF OBSERVATION WELL & PIEZOMETERS TO STUDY FLOW OF GROUNDWATER (USDA, SCS, NO. 16)

Observation well

The W.T. is the upper limit of the waterlogged soil. It can be determined by digging a hole in the soil and observing the height to which the hole fills with water. Observation wells are used to measure the W.T. These are open holes which are partially filled with gravel and a perforated pipe is placed in the hole. The region around the pipe is then backfilled with gravel so that water can flow freely into and out of the pipe and the hole. Observation wells will give accurate measurements of the height of W.T. provided there is no artesian pressure.

Size of observation wells

Water surface fluctuations within large diameter observation wells often lag considerably behind actual W.T. fluctuations in slowly permeable soils because of large water storage in the well. Reducing the well diameter reduces lag factor. A diameter of 20 to 25 mm proves to be quite satisfactory under normal conditions.

Spacing

There should be no set rule for spacing observation wells. One may follow the procedure of 'dig and try' as the investigation proceeds. The study of W.T. levels observed in the wells will show if additional wells need to be installed.

Depth

Generally, a water level below 2.5 metres is not significant in drainage planning. There, the wells to the depth of 2.5 to 3.0 m will be adequate except where artesian conditions exist.

Well elevation

In order to correlate W.T. levels with G.L. and to prepare groundwater contour maps, it is necessary to determine the elevation of each observation well and the ground surface at that point.

Recording data

Periodic measurement on W.T. levels in the observation wells should be made. The data should be processed to show the actual elevation of water level and show the depth of W.T. below the ground surface. Lines of equal depth are joined and a map similar to a contour map is obtained. Such a map clearly indicates areas of high W.T. and can indicate the source of drainage water.

Period of measurements

Observation wells should be established to function for a period of at least one year. In high rainfall area (tropical climate), the observations shall be recorded daily. The most valuable measurements can be obtained if an automatic water stage recorder is placed on an observation well to give continuous record of W.T. fluctuations. The data serve a good purpose in designing the drainage systems.

Piezometers

Piezometer is a useful tool to measure the soil water pressure and to determine groundwater conditions where artesian pressures are suspected. Piezometer is a small diameter pipe driven into the subsoil so that there is no leakage around the pipe and all entrance of water into the pipe is only through the open bottom. The piezometer indicates only hydrostatic pressure of groundwater at the specific point in the soil where the open end of the piezometer pipe is located. The water pressure is measured by the elevation of water in the pipe. The pressure head is the distance between the end of pipe and the elevation of water in the pipe. Several piezometers need to be placed side by side at different depths to measure the vertical gradient of water in the soil to find out if there is any artesian pressure. Artesian pressure is indicated if the water in the deeper piezometers rises to a greater elevation than the water in the shallower piezometers. Small diameter pipes (10 to 15 mm) are used for piezometers.

Groundwater conditions on Alluvial Fan (Fig. 1.8)

An alluvial fan can be divided into three zones:

Recharge zone.
Transmission zone
Discharge zone.

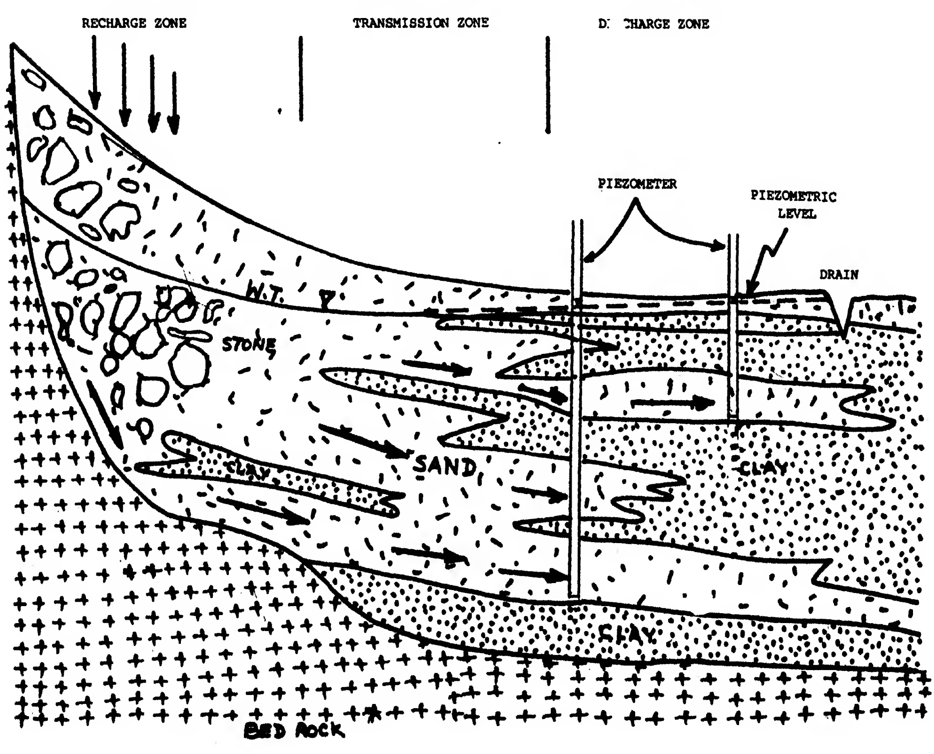


FIG. 1.8 GROUNDWATER CONDITION IN ALLUVIAL FAN

The recharge zone comprises the pervious gravel fields at the head of the alluvial fan. Because of the generally coarse grained deposits, the groundwater in this zone is confined. The watertable is relatively deep and rather flat due to the high permeability of the gravels and coarse sands. The aquifer is recharged by infiltrating rainfall, runoff from mountain front and by sub-surface inflow.

The transmission zone starts where clay layers are found in the subsoil; as a consequence, the deeper pervious layers are semi-confined aquifers. The surface layers present a phreatic aquifer that is recharged by flood water and rainfall. Under the influence of the differences in hydraulic head between the various pervious layers, water will flow upward and recharge the phreatic reservoirs. The topographic slope is generally steeper than the slope of the water table and of the piezometric surface. This means that in down-stream direction the water table is increasingly closer to the ground surface. The piezometric levels become higher and may even rise above ground surface so that deep wells may yield free flowing water.

The discharge zone is found in the lower part of the fan where the topographic slope is slight and the water table shallow. Here too, the water in the deeper layers is under pressure and a vertical upward flow exists. Springs are often at the foot of the fan, yielding water. Drainage problems are generally limited to this part of the fan.

2

SOIL PROPERTIES AFFECTING DESIGN OF DRAINAGE SYSTEM

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Introduction

Soil-plant-water relationships relate to the properties of soil and plants that affect the movement, retention and use of water. Soil provides the room for water. Due to uneven distribution of high intensity and heavy amount of rainfall during growth period of tea, it becomes essential to effectively and efficiently remove the water from soil surface and from sub-surface that is in excess to the plant requirement. Hence, it is important to know the soil physical and hydraulic properties in relation to soil water retention, movement and drainage.

Soil

The term 'SOIL' is often used loosely and conveys different things to different people. The soil physicist considers soil as a porous medium. The soil chemist sees the soil as a powder, fine or coarse grained having complicated chemical and physical properties. For agronomists, the soil is a medium for plant growth and he is more interested in top soil. The drainage specialist is mainly concerned with soil properties which affect the movement of water into and through soils.

Components of soil

Soil is regarded as a porous medium i.e. a material system in which solid, liquid and gaseous materials are present. In mineral soils, the mineral materials occupy upto 50-60% by volume and organic matter generally less than 3%. Soils provide plants with essential plant nutrients in addition to water and oxygen for root respiration, in absence of which, the rate of up-take of nutrients is reduced.

Soil profile

The vertical section through the soil is called the soil profile (Fig. 2.1). Soil profile coincides with the rootzone of crops and is usually limited to upper 1.50m. The soil profile consists of two main layers; the top soil and the subsoil. In drainage and irrigation, we are interested in the water intake

rate of the top soil, water holding capacity, water transmitting properties soil workability, structural stability and fertility status.

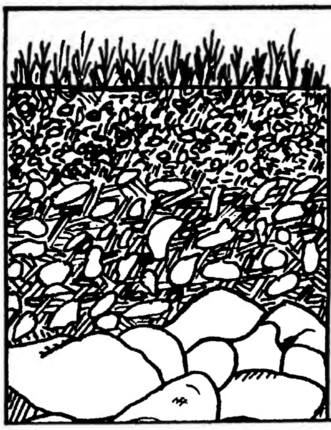

FIG. 2.1 PROFILE OF SOIL FORMED IN PLACE

Soil Investigations

A. Physical and hydraulic properties

Texture, structure, compactness, bulk density, particle density, moisture retention, moisture release, permeability, porespace, infiltration rate.

B. Chemical properties

pH, N, P, K, Ca, Mg, trace elements and organic matter.

This lecture will be limited to discussion on soil physical and hydraulic properties only.

1. Soil texture

The size distribution of soil particles is referred to as 'Texture'. The main particle size limits are given in Table 2.1.

Table 2.1 Particles size limits

Soil	Particle size, mm
Very coarse sand	1.00 - 2.00
Coarse sand	0.50 - 1.00
Medium sand	0.25 - 0.50
Fine sand	0.10 - 0.25
Very fine sand	0.05 - 0.10
Silt	0.002 - 0.05
Clay	≤ 0.002

The relative proportion of sand, silt and clay in soil determines its textural class. Normal soil textural classes are given in Table 2.2.

Table 2.2 Common classes of Soil Texture

Textural term	Textural class
Coarse	Sand
Light	Loamy fine sand, loamy sand, fine sandy loam, sandy loam
Medium	Silt loam, loam
Heavy	Silty clay loam, clay loam, sandy clay loam, silty clay, sandy clay, clay
Very heavy	Heavy clay

Sandy loam soils are considered most favourable for growth of tea plants because they hold enough water, are better aerated and are easier to work with. Fig. 2.2 presents the textural classification chart for 12 main textural classes.

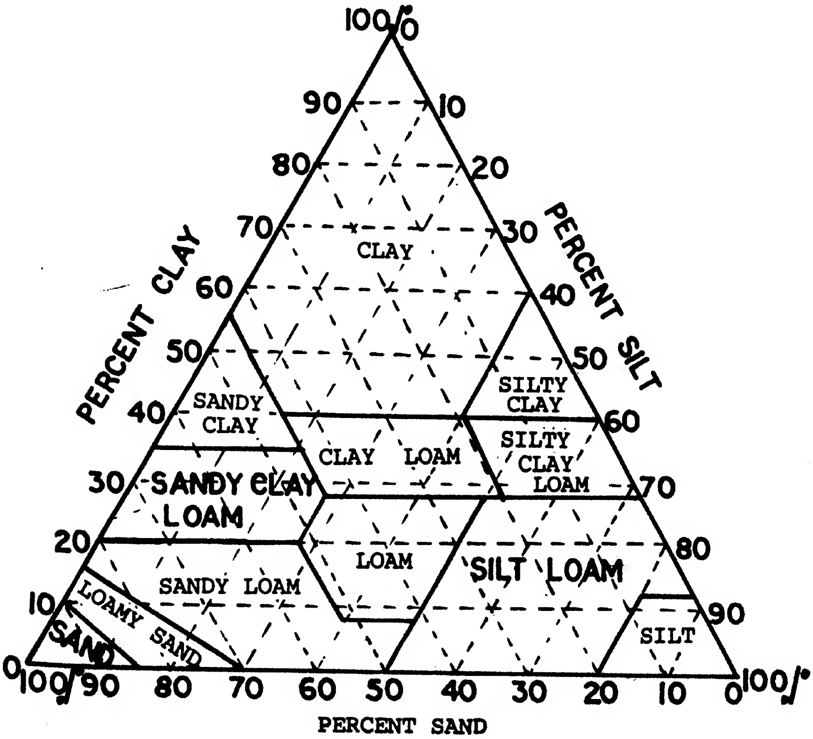

FIG. 2.2. TEXTURAL TRIANGLE TO CLASSIFY SOIL TYPE (USDA)

2. Soil structure

The arrangement of individual soil particles with respect to each other into a pattern is called soil 'structure'. The structure is classified into:

i) Cube-like structure
ii) Columnar structure
iii) Platy structure
iv) Angular structure
v) Granular structure.

Soil structure has a pronounced effect on such soil properties as porosity, permeability, infiltration, water holding capacity, water transmissibility, soil stability and erodibility.

A massive compact soil restricts aeration and root spread. For optimum crop growth, soil structure should be such that the infiltration capacity is large, percolation capacity is medium, and aeration is sufficient.

The common methods of soil structure management are proper land use, suitable tillage practices, optimum soil moisture, sub-soiling, addition of organic matter, application of optimum level of fertilizers, mulching, drainage and soil conservation practices.

3. Bulk density

It is defined as the ratio of mass of soil solid to its volume. It is also referred to as 'Apparent Specific Gravity'.

$$\varrho = \frac{M}{V}$$

Normally, the bulk density of soil particles is 1.55 grams/cc.

4. Apparent specific gravity

It is defined as the ratio of the weight of soil and the weight of an equal volume of water. It is dimensionless. The apparent specific gravity is influenced by structure, texture and compactness.

5. Porosity

Porosity can be defined as the ratio of the volume of pores to the total soil volume.

$$n = 100 \left(1 - \frac{As}{Rs}\right)$$

Where : n = porespace, %
As = Apparent specific gravity,
Rs = Real specific gravity (2.65).

In general, coarse textured sandy soils have a smaller percentage of total pore space and fine-textured clay loams and clays have a greater percentage. But the sandy soils have large air filled porosity as compared to clay soils.

Porespace has a direct bearing upon productive value of soils because of its influence upon water holding capacity and upon the movement of air,

water and roots through the soil. When the air filled porespace of a soil is reduced by 10%, the movement of air, water and roots is greatly restricted and growth is very seriously impeded.

6. Capillary and non-capillary pores

The capillary pores contain water which remain after most of the free drainage in the soil is completed. Capillary porosity is the percentage of pore space that may be occupied by capillary water. Non-capillary pores do not hold water tightly by capillary. It is the percentage of pore space that is filled with air after the soil has drained to the field capacity. The porosity has considerable significance with respect to plant growth. The large non-capillary porosity of sandy soils results in better drainage and aeration but it also results in a lower water holding capacity than clay soils, which have a larger proportion of small capillary pores. An ideal soil has enough large pores to permit adequate drainage and aeration and enough small pores to give adequate water holding capacity.

7. Soil colour

When the colour of a soil is considered in conjunction with other observable features - structure, texture and consistency - a great deal can be inferred as to the soil's physical and chemical conditions. Colour is dependent on the nature of the parent material from which the soil is formed, drainage and on the soil temperature. In aerated soils, the colours can be dark brown, almost black when humus particles predominate, or they can be yellow to red due to coatings of more or less hydrated iron compounds. In waterlogged soils grey-greenish colour occur due to the reduction of ferric iron to ferrous iron. The horizon may be uniform in colour or it may be mottled, i.e. the occurrence of patches of red, yellow and other colours due to oxidation after a period of reduction under temporary waterlogged conditions. In the impeded aeration conditions, the colour of channels of living roots is grey or green and of dead roots is rusty yellow and brown.

8. Soil air

Plant roots and most soil microorganisms utilize oxygen from the soil air and give off carbondioxide. A continuous supply of oxygen is needed for this process. An insufficient supply will limit plant growth. Improving the soil aeration is one of the main objectives of drainage. The pore space of a soil (40 to 50%) is occupied by water and gases. A comparison of soil air and atmospheric air is given in Table 2.3.

Table 2.3 Composition of Soil Air

Gas	Atmospheric air	Soil air
N	79%	79%
O_2	20.97%	20.5 to 20.8%
CO_2	0.03%	0.2 to 0.5%

Under waterlogged conditions, CO_2-content of soil air may increase to over 1% and may even become as high as 15%. There is a general inverse

relation between O_2 and CO_2 contents ; when CO_2 increases, O_2 decreases. *The sum of soil air's O_2 and CO_2 is about 20.97%. There is an inverse relationship between soil air and soil-water. An excessive amount of water implies a shortage of soil air. As a rule of thumb, it can be said that a soil* is well aerated if it has an aeration porosity of 10% on a volume basis.

Due to the respiration processes of roots and microbes, the partial pressure of O_2 is reduced below that of the atmosphere, resulting in a movement of atmospheric O_2 into the soil whilst the partial pressure of the CO_2 rises above its normal atmospheric content, resulting in an outward movement of CO_2. Diffusion must take place through air-filled pores, since air cannot diffuse readily through a water layer.

The aeration requirement of tea plant and its tolerance for poor aeration conditions is not known. But it is clear that poor aeration conditions impede uptake of nutrients and water and curtail its growth of roots.

Nitrogen fixation by aerobic microbes is of great importance in soil and is strongly influenced by aeration. The lack of sufficient air prevents the oxidation of nitrogen and sulfur into forms that plants can readily utilize.

The amounts of soluble iron and manganese are strongly influenced by the O_2 concentration of the soil air as they are by the pH of the soil. When anaerobic processes are periodically replaced by aerobic reactions, iron and manganese may accumulate in the soil in the form of concentrates. Under anaerobic conditions both inorganic and organic toxic substances may develop. In general, a high CO_2 content increases the solubility of phosphorus and calcium carbonate.

9. Soil temperature

Along with water, air and nutrients, another important growth factor for plants is the temperature of the soil. Microbiological activity and root growth are greatly affected by the soil temperature.

Soils with well-drained subsoil warm-up more quickly and to a greater depth than do soils with a higher water content, hence the importance of good drainage.

Microbiological activity gets highly restricted below a temperature of 10°C and thus decreases the availability of nitrogen, phosphorus and sulfur.

10. Movement of water within soils (Fig. 2.3)

The movement of water within the soil controls not only the rate of infiltration but also the rate of supply of moisture to plant roots and the rate of underground flow to springs and streams and recharge of ground water. Water moves through the pore-spaces under influence of gravity.

(a) Infiltration

It is the rate at which water enters into the soil. It is influenced by soil properties.

(b) Intake

The rate of infiltration from a furrow into the soil is referred to as the intake rate.

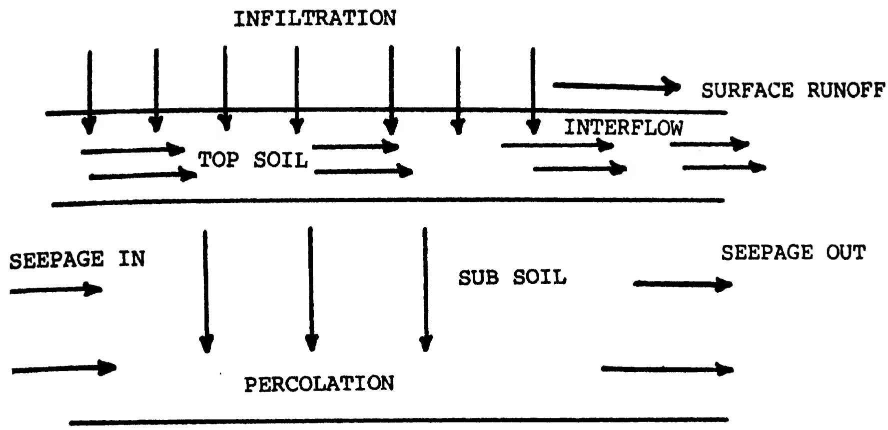

FIG. 2.3. COMPONENTS OF WATER FLOW IN THE SOIL

(c) Percolation

It is the downward movement of water through saturated soil in response to gravitational force. Percolation occurs when water is under pressure or when tension is smaller than 1/3 atmosphere.

(d) Interflow

It is the lateral seepage of water in a relatively pervious soil above a less pervious layer. Such water usually reappears on the surface of the soil at a lower elevation.

(e) Seepage

Seepage is the vertically downward flow and lateral movement of water into soil or substrata from a source of supply upslope.

(f) Permeability

It is defined as the velocity of flow caused by a unit hydraulic gradient. In drainage the term hydraulic conductivity is more commonly used. It is defined as the proportionality factor 'K' in Darcy's law ($v=Ki$). The values of K depend on the properties of fluid as well as those of the soil. A soil that has high porosity and coarse open texture has a high hydraulic conductivity.

(g) Hydraulic head

It is the elevation with respect to a standard datum at which water stands in a manometer connected to the desired point in soil. This will include elevation head, pressure head and also the velocity head, Fig.2.4.

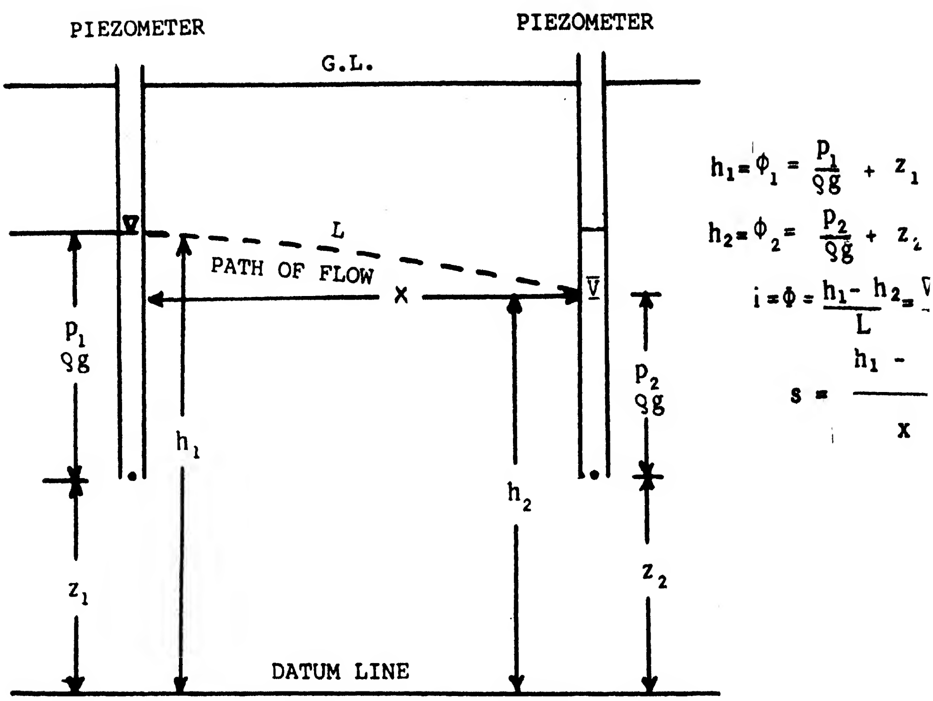

FIG. 2.4 ILLUSTRATION OF HYDRAULIC HEAD AND GRADIENT

$$H = \frac{v^2}{2g} + \frac{P}{\rho g} + z \text{ , where}$$

H = hydraulic head

$\frac{v^2}{2g}$ = velocity head

$\frac{p}{\rho g}$ = pressure head

z = elevation head

In soils, since the velocity head is negligible,

$$H = \frac{P}{\rho g} + z$$

(h) Hydraulic gradient

It is the rate of change of piezometric or hydraulic head with distance.

(i) Darcy's law

The theory of water movement in soils is based on Darcy's law, i.e.

$$V = K\ i$$

Where:

v = velocity of flow, m/day
K = hydraulic conductivity, m/day
i = hydraulic gradient $= \frac{h_1 - h_2}{L}$

h_1 & h_2 = hydraulic heads at points of measurement 1 and 2, m
L = distance between the two points, m.

(j) Equation of continuity

The law of conservation of mass states that in a closed system the fluid mass can be neither created nor destroyed. The equation representing this law is:

$$\frac{\partial V_x}{\partial x} + \frac{\partial V_y}{\partial y} + \frac{\partial V_z}{\partial z} = 0$$

(k) Laplace's equation

Application of Darcy's law and the equation of continuity to three--dimentional flow through soil results in Laplace's equation, i.e.

$$\frac{\partial^2 \Phi}{\partial x^2} + \frac{\partial^2 \Phi}{\partial y^2} + \frac{\partial^2 \Phi}{\partial z^2} = 0 \quad \text{OR} \quad \nabla^2 \phi = 0$$

(l) Effective rainfall

Effective rainfall means useful or utilizable rainfall. Rainfall is not necessarily useful or desirable at the time, rate or amount in which it is received. Some of it may be unavoidably wasted while some may even be destructive. Just as the total rainfall varies, so does the amount of effective rainfall. Drainage engineers define effective rainfall as that portion of total rainfall which contributes to ground water table. Effective rainfall is influenced by rainfall characteristics, land slope, soil properties, ground water characteristics, management practices, crop characteristics, carry over soil moisture, groundwater contribution, surface and subsurface inflow and outflow, and deep percolation etc.

(m) Soil moisture retention and movement

The moisture content of a sample of soil is usually defined as the amount of water lost when dried at 105°C. Though important, soil moisture is not a clear indication of water that is available for plant and that in excess to the plant requirement. The forces that keep soil and water together are based on the attraction between water and soil molecules (adhesive) and among water molecules themselves (cohesive). In the wet range, surface tension is the most important force while in the dry range adsorption is the main factor.

(n) Kinds of soil water (Fig. 2.5)

The main classes of soil water are:

i)	**Hygroscopic water**	: It is held by adsorption forces.
ii)	**Capillary water**	: It is held by surface tension.
iii)	**Free water**	: It is under the influence of gravitational force and drains out of soil.

i) Hygroscopic water

This water is not available to plants for growth, it is normally held between tensions of 10,000 and 31 atmosphere.

ii) Capillary water

It is held between tensions of 31 and 1/3 atmosphere, capillary water is the only fluid water bearing solutes that remain in the soil for any length of time. It therefore, functions as the soil solution. It is affected by soil texture, structure and organic matter.. The finer the texture, the greater is capillary capacity. Granular soil structure produces higher capillary capacity. Presence of organic matter also increases the capillary capacity.

In the wilting point range, when tensions are between 31 and 15 atmosphere, capillary movement is very sluggish.

iii) Free water

This water is held in the soil at tensions less than or equal to 1/3 atmosphere above the field capacity level. It moves freely in response to gravity. It is, therefore, called free water or gravitational water. This water, in general, is in excess to plant requirement and needs to be drained off.

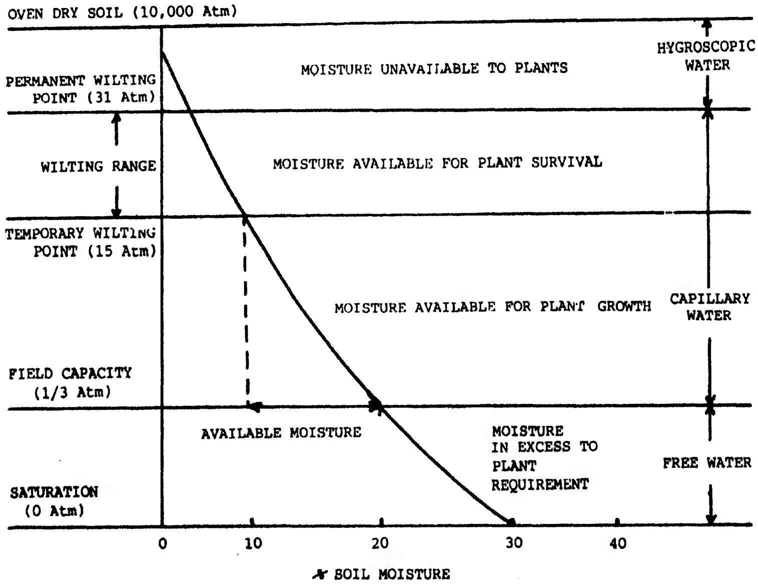

FIG. 2.5. FORMS OF SOIL MOISTURE AND THEIR AVAILABILITY

3

TECHNIQUES OF TOPOGRAPHIC SURVEY

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LAND SURVEYING

Land surveying is necessary for the following:

1 To describe the boundary of a piece of land precisely.
2 To determine its area
3 To obtain data for preparing a plan.

The following methods are used for land surveying:

1 Triangulation
2 Traversing

TRIANGULATION SURVEY

In this method of surveying, the sides of the various triangles are computed from (i) the single line measured directly called the base line, and (ii) the three angles of each triangle measured accurately by a theodolite.

Chain triangulation or Chain surveying

In this method of surveying, the sides of various triangles are measured directly in the field and no angular measurements are taken. In chain surveying it must be remembered that:

(i) The triangles should be as far as possible equilateral.
(ii) Triangles should not contain angles less than 30° or greater than 120°.

Survey stations

A survey station is an important point and is located at the beginning and end of a survey line. There are two kinds of stations:

(i) Main
(ii) Subsidiary or tie

Main stations are located at the ends of survey lines which command the boundaries of the area, and the subsidiary or tie stations are the points selected on the main survey lines where it is necessary to draw auxillary lines to locate the interior details such as fences, roads, bridges, hedges etc. The main stations are denoted with a triangle Δ or small circle around the stations and they are lettered or numbered.

The main stations are selected in such a way that they are mutually visible. Each main station should have permanent or semi-permanent reference marks as follows:

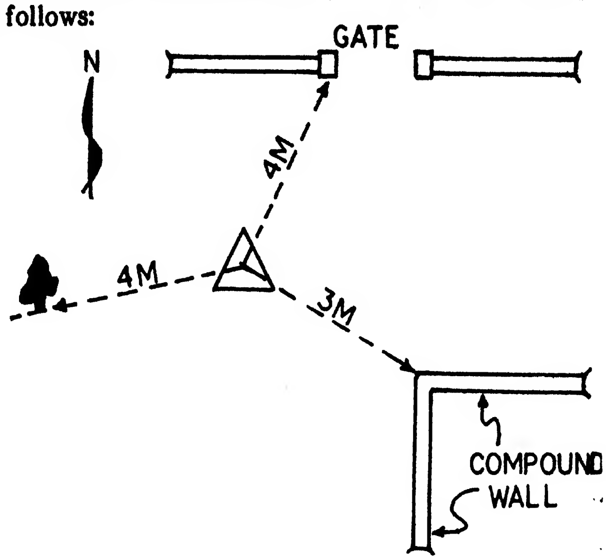


FIG. 3.1 MARKING OF STATIONS WITH REFERENCE OBJECTS

The following salient points should be noted while arranging the frame work of a survey:

1. The surveying should be commenced from the whole to the part.
2. All triangles should be well conditioned i.e. as far as possible equilateral.
3. The main stations should be mutually visible.
4. The survey lines should be as few as possible.
5. A number of subsidiary survey lines called 'tie lines' should be drawn to locate details so that long offsets are avoided.
6. The survey lines should be arranged in such a way that obstacles are avoided.
7. As far as possible the survey lines should lie on level ground.
8. As far as possible the sides of larger triangles should pass parallely close to the boundary roads, buildings etc.

Base line

The longest of the chain lines is generally regarded as the base line as it fixes up the directions of all other lines. This is an important line on which the frame work of survey is build up. It should be laid off on level ground through the centre and the length of the area. The base line should be correctly measured.

Check line

The check line or proof line is a line drawn from the apex of a triangle to some fixed point on the opposite side. It is used to check the accuracy of the framework.

Tie line

A tie line is a line joining some fixed points on the main survey line. It serves dual purpose, viz. it checks the accuracy of the framework and locates interior details which are far away from the main chain line.

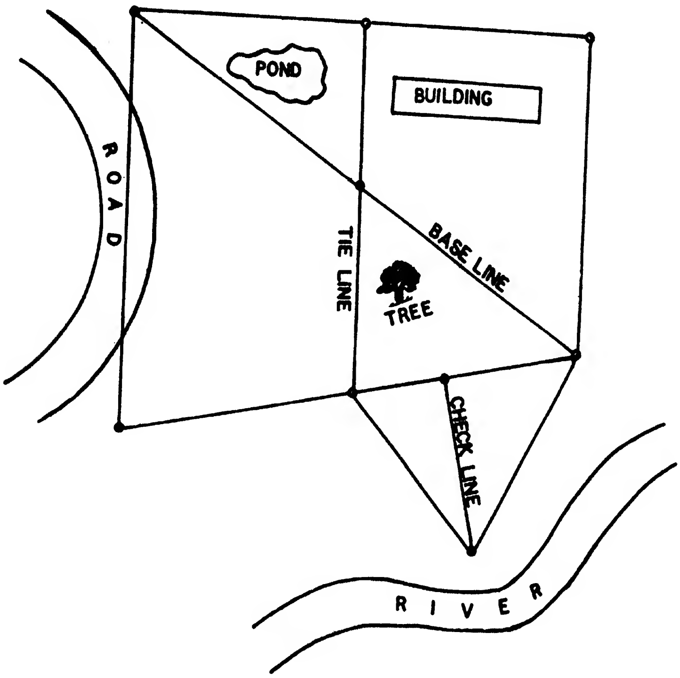


FIG.3.2 SHOWING BASE, TIE AND CHECK LINES

OFFSETS

Offsets are lateral measurements taken to locate the details such as boundaries, buildings, fences, roads, nullahs etc. with respect to the survey lines.

Offsets are always taken at right angles to the survey line. For better accuracy, offsets should be as short as possible.

Taking offsets

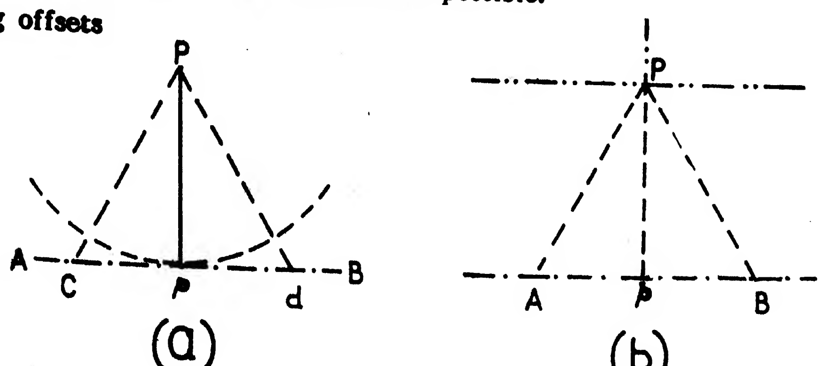


FIG.3.3 TAKING OFFSET WITH TAPE

When an offset is to be taken to a point, say, P (Fig.3.3a), the leader holds the zero end of the tape at P and the follower, carrying the tape box, swings it along the chain in a short arc about the point P as a centre and *finds point p of the minimum reading, which is the foot of the perpendicular from P to line AB. The follower inserts an arrow at point p so found and* measures the distances pP.

Fig.3.3b shows an oblique offset. Here the swinging tape makes an arc touching point c and d and the distance cd is measured. The mid point of measurement will give the point p where the object is perpendicular to point P. At point, p, the follower inserts an arrow and the perpendicular distance pP is measured.

Number of offsets

The number of offsets to be taken depends upon the nature of the object. Sufficient number of offsets should be taken so that the object is defined clearly and accurately. Whenever the outline of the object changes direction, an offset must be taken at the points of change in direction.

FIELD WORK

Equipments

i) A chain & 10 steel arrows
ii) Cotton or metallic tape
iii) An offset rod
iv) An optical square or cross staff
v) A plumb bob
vi) A survey field book
vii) Wooden pegs & a mallet
viii) Good pencils & pen knife
ix) Compass

Procedure

1. Reconnaisance

The preliminary inspection of the area to be surveyed is called reconnaisance.

Prior to commencement of surveying, it is essential that the surveyor should have thorough knowledge of the ground to be surveyed and its principal features. He should walk over the area and thoroughly examine the ground and make notes of the various boundaries, the positions of objects, and various obstacles, difficulties he is likely to encounter. He should determine the proposed positions of the stations and check their intervisibility. He should also make mental notes on the proposed size of triangles and length of survey lines. During reconnaisance, the surveyor should prepare a neat hand sketch called index sketch or key plan, fairly resembling the plan on the ground in the field survey book.

2. Marking stations

Having completed the reconnaisance, the survey stations are marked on the ground as follows:

(a) By fixing vertically ranging rod or pole at each station.
(b) By driving in firmly a wood peg at each station.

Reference sketches

After the stations are marked on the ground, they should be provided with at least three permanent or semi-permanent reference points as described above. These reference points are located by measurements and should be recorded on the field survey book.

4. Running the survey lines

Having completed the preliminary work, chaining should commence from the base line and carried throughout all the lines of the framwork as continuously as possible. While chaining is in progress, the details should be filled up by taking offsets as explained above. The process of chaining and taking offsets is repeated until the end of the line is reached. Other lines are similarly dealt with.

Instruments for setting-out Right Angles

1. Open cross staff

It has four metal arms with vertical slits at right angles to each other for sighting through.

To take offset at right angle to the chain line, the cross staff is held vertically on the chain line at a point where the offset is likely to occur, and turned until one pair of the opposite slits is directed to a ranging rod at the forward end of the chain line. Looking through the other pair of slits, it is seen if the point to which the offset is to be taken is bisected. If not, the cross staff is moved forward or backward on the chain line until the line of sight through the pair of slits at right angles to the chain line does bisect the point.

2. Optical square

The optical square is also used for the same purpose as cross staff. It is a brass wedge - shaped hollow box of 5cm in sides and 3 cm deep with a handle of 7.5cm long. There are two mirrors which are fixed at an angle of 45° to the inclined sides of the box. There are two rectangular openings above these mirrors for sighting. While sighting the object, the open face of the square should be directed towards the object to which the offset is to be taken. While directing the opening towards the object, the surveyor should look towards the ranging rod fixed at the forward station. The surveyor than walks forward and backward until the image of the object appears exactly in line with the ranging rod at the forward station.

Tape

$5^2 = 3^2 + 4^2$

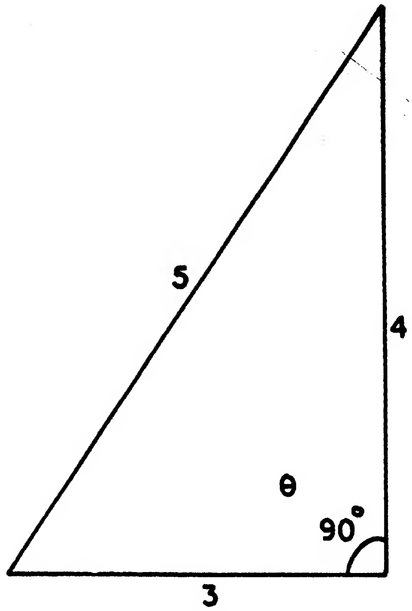


FIG. 3.4 RIGHT ANGLE TRIANGLE IN THE RATIO OF 3:4:5

This method is also called as 3:4:5 method. Here the angle θ will be always 90 i.e. right angle if the sides of the triangle are in the ratio of 3:4:5. In the field, accurate right angle triangles can be laid out by using tape following the above measurements maintaining the ratio.

Surveying and booking field notes

A survey field book of 20cm x 11cm size is used for recording the field measurements and sketches. In booking the field notes, we start at the bottom of the page and work upwards as if we are writing them on actual chain line. At the commencement of the chain line, the following should be written in the book:

i) The name or number of the survey line.
ii) The name or number of the station.
iii) The symbol Δ closing stations.
iv) Tie stations should be indicated by a circle round their chainage figures.

As the chaining progresses, all distances along the chain line are entered in the central column and the offsets written opposite them on the right or left of the column accordingly as they are right or left of the survey line. The nature and form of the objects to which offsets are taken should be sketched with conventional signs and names written along them. At least 1 cm space should be left between two entries to avoid over crowding. At the end of the line, closing chainage should be enclosed in the symbol Δ and the name or number of the station and the name or number of the chain line should be written clearly,(Fig.3.5).

The following points are useful:

(1) Each chain line should be recorded on separate page.
(2) Record all measurements as soon as they are taken. Notes should be complete, and nothing should be left to memory.
(3) Notes, sketches and figuring should be neat, clear and legible.
(4) Entries should be recorded in pencil.
(5) Explanatory notes and references to other pages, where necessary, should be given.

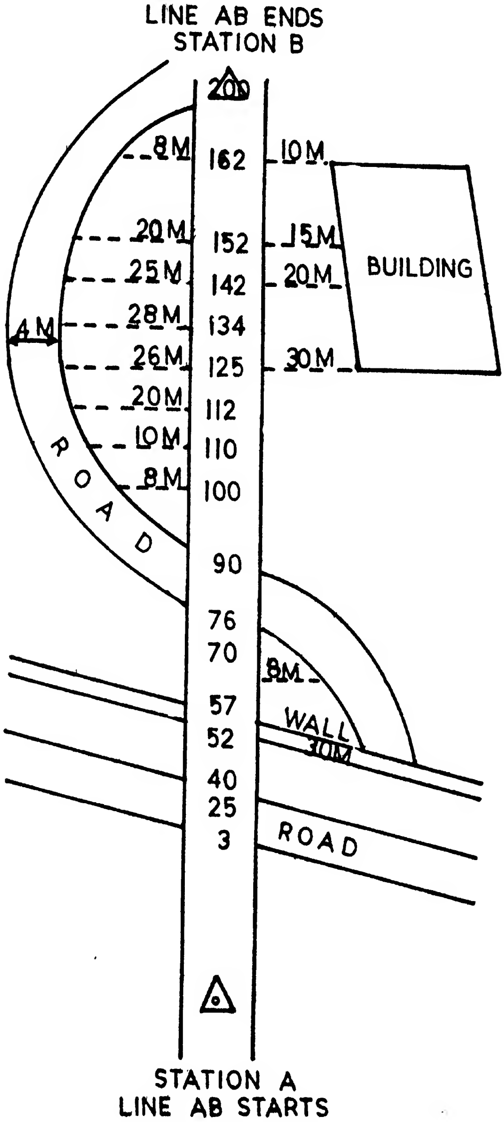


FIG. 3.5 A PAGE FROM THE FIELD SURVEY BOOK SHOWING METHOD OF BOOKINGS

Obstacles in chaining

Various obstacles such as woods, hills, ponds, building etc. are continually met with in chaining. It is however, essential that chaining should be continued in a straight line. The obstacles may be classified as follows:

(1) Obstacles which can be chained across but are not visible.
(2) Obstacles which are visible, but cannot be chained.
(3) Obstacles which can neither be seen or chained across.

1. Vision obstructed, chaining possible

(a) Both ends are visible from intermediate points on the line,(Fig.3.6)

This problem can be solved by the method of reciprocal ranging as follows:

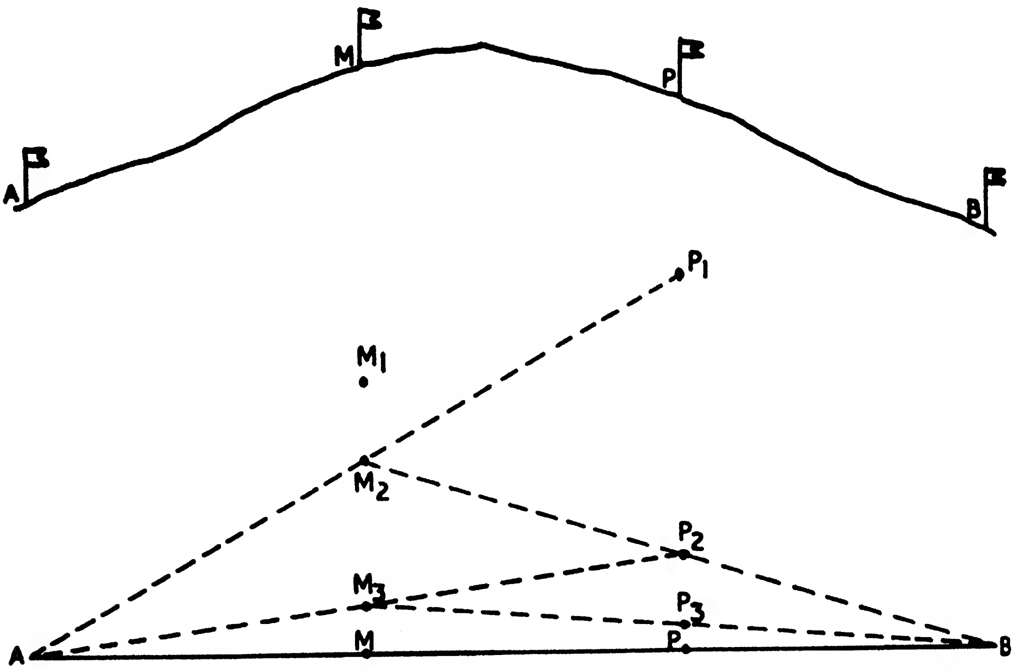


FIG.3.6 RECIPROCAL RANGING

Let A and B are two points and in between there is a hill. Point A is not visible from point B, but the survey line A and B has to be measured. Let two chainmen with ranging rods take up positions at M, and P, such that both of them can see the ranging rods at A and B. The chainman at P_1 directs the chainman at M_1 to move to M_2 in line with A and then the chainman at M_2 directs the chainman at P_1 to P_2 in line with B. By successively directing each other into line, their positions will be changed until finally they are both in the line AB exactly when they fix up their ranging rods.

(b) Both ends of the survey line may not be visible from any intermediate points.

In such a case, the method of random line should be followed (Fig. 3.7).

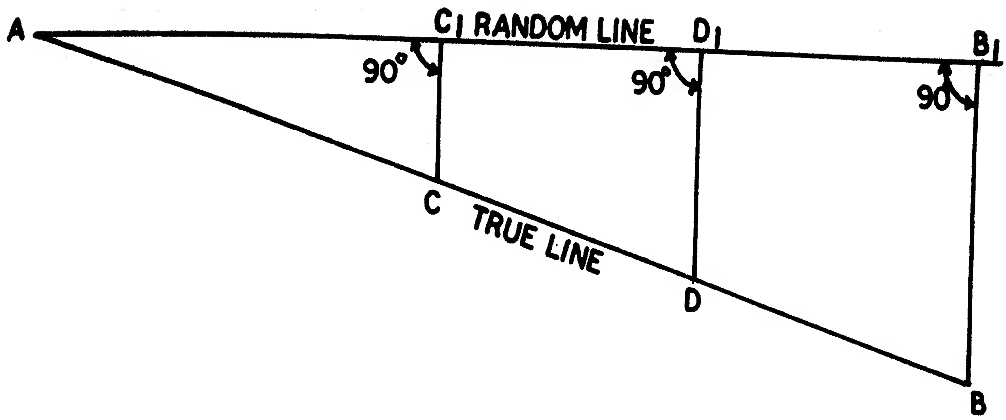


FIG.3.7 RANDOM LINE METHOD

Let A and B the line whose length is required. From A run a line AB_1 called a random line in any convenient direction, but as nearly towards B as can be judged and continue until B is visible from B_1. Chain the line to B_1 where BB_1 is perpendicular to AB_1 and measure BB_1.

$$AB = \sqrt{(AB_1)^2 + (BB_1)^2}$$

2. Chaining is obstructed, but vision is free:

This situation may arise when a pond, plantation or tank is encountered while surveying. Any of the following methods can be adopted, Fig. 3.8(A).

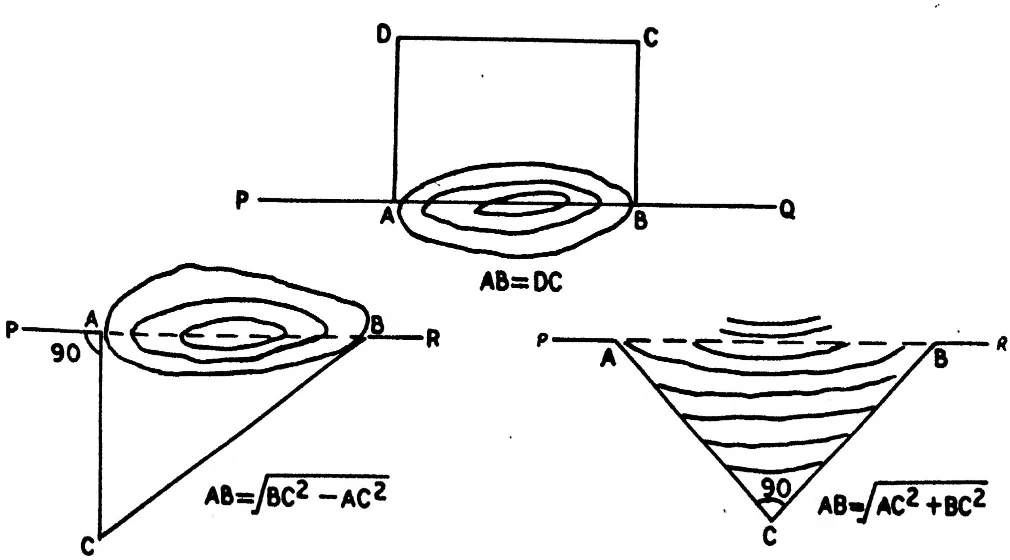


FIG.3.8(A) OBSTACLE CHAINING

3. Chaining and vision both obstructed, Fig. 3.8(B).

Select two points A and B on the chain line PR on opposite banks of the river. Set out a perpendicular AD and bisect it at C. At D, erect a perpendicular DE and mark the point E in line with C and B. Measure DE. Since the triangles ABC and CED are similar, AB = DE (Fig. 3.8(B).

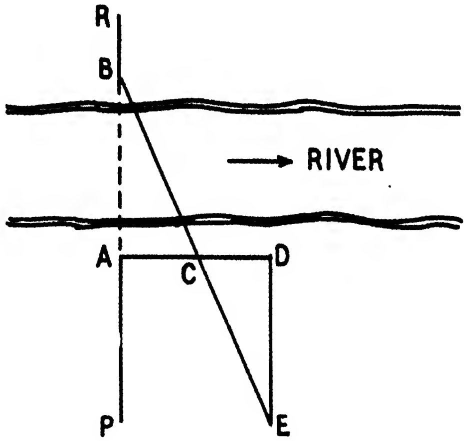


FIG.3.8 (B) OBSTACLE CHAINING

Computation of area

1. Triangle = ½ base x altitude

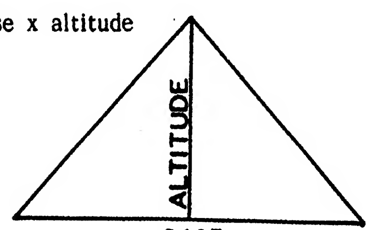


FIG.3.9 EQUILATERAL TRIANGLE

2. Square $= (\text{Side})^2 = \frac{1}{2}(\text{Diagonal})^2$

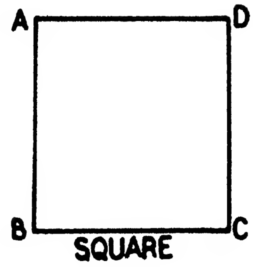


FIG.3.10 SQUARE

3. Rectangle = Product of two adjacent sides.

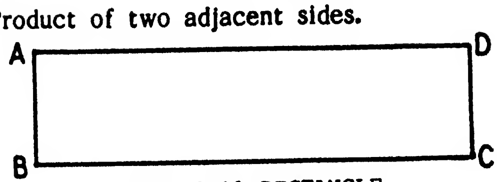


FIG. 3.11 RECTANGLE

4. Parallelogram = (Base x height)

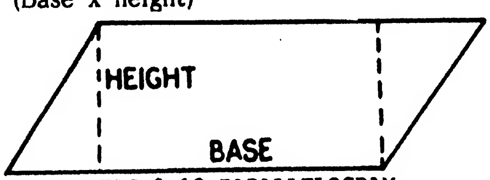


FIG.3.12 PARALLELOGRAM

5. Rhombus = Base x height
product of two diagonals

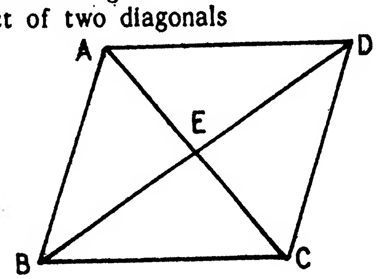


FIG.3.13 RHOMBUS

6. Trapezoid $= \frac{1}{2}$ sum of two parallel sides x perpendicular distance between them.

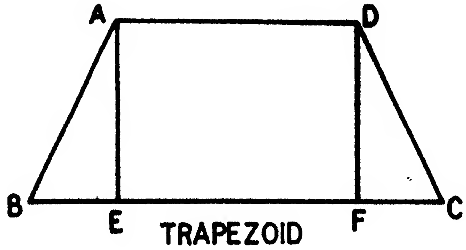


FIG.3.14 TRAPEZOID

7. Area under curved boundaries

(i) The Trapezoidal rule

In this method the area is divided into a series of trapezoides and the area is calculated as follows, (Fig. 3.15).

"To the sum of the first and the last ordinates, add twice the sum of intermediate ordinates. Multiply the total sum thus obtained by the common distance between the ordinates. One half of this product gives the required area".

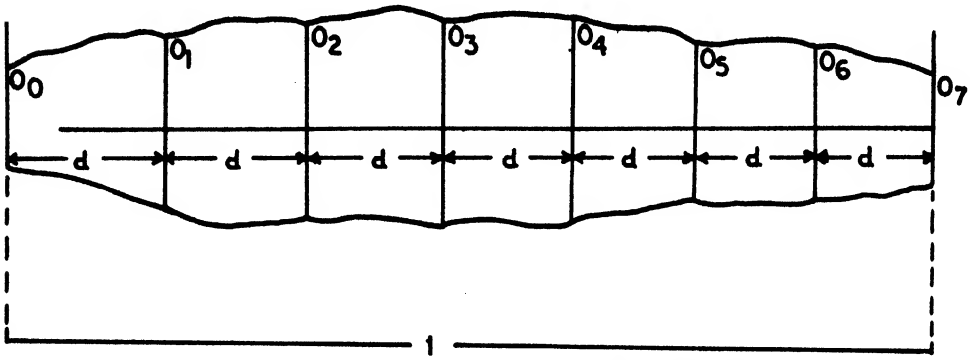


FIG. 3.15. CALCULATION OF AREA BY TRAPEZOIDAL RULE

$$= \frac{d}{2}(O_0 + 2O_1 + 2O_2 + \text{----------} + 2O_{n-1} + O_n)$$

(ii) Simpson's Rule

This can also be found out by Simpson's Rule. The Rule says "To the sum of the first and the last ordinates, add twice the sum of the remaining odd ordinates and four times the sum of all the even ordinates. Multiply the total sum thus obtained by one third of the common distance between the ordinates and the result gives the required area", (Fig. 3.16)

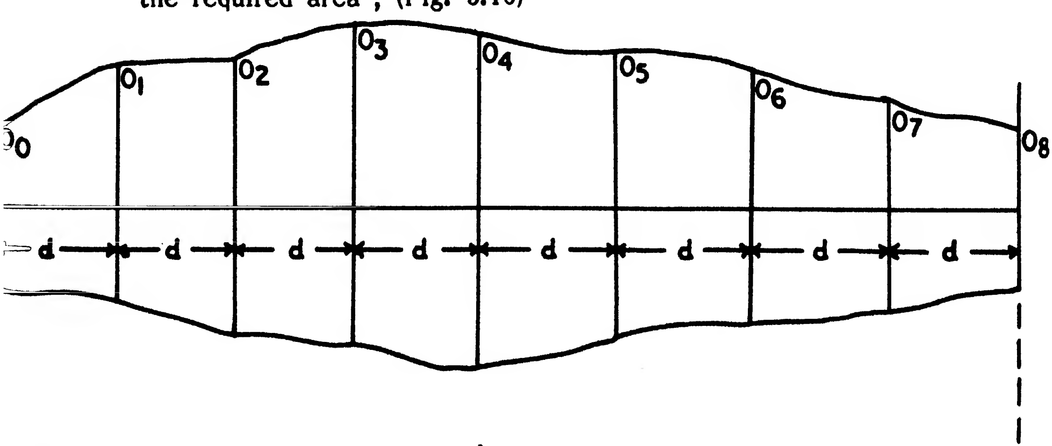


FIG. 3.16. CALCULATION OF AREA BY SIMPSON'S RULE

$$\text{Area} = \frac{d}{3}(0_0 + 40_1 + 20_2 + 40_3 + \text{-------} 20_{n-2} + 40_{n-1} + 0_n)$$

In this method, it is essential that the area is divided into even numbers i.e. the total number of ordinates must be odd. If there is odd number of divisions resulting in even number of ordinates, the last division must be calculated separately and added to the result obtained by Simpson's Rule.

Plotting

Once the field work is complete, this should be plotted on drawing sheet for preparation of maps, plans etc. The following drawing instruments are required;

1 Drawing table
2 Drawing board
3 A Tee square
4 A set of setsquares
5 A ruler
6 An instrument box
7 A protractor
8 A compass
9 A set of scales

Drawing materials

The following drawing materials are needed:

1 Drawing paper
2 Drawing pins
3 Weights
4 Pencils
5 India rubber or eraser
6 Ink
7 Colours
8 Brushes

Before the actual plotting starts, the scale of the plant should be choosen. A border line may be drawn on the paper leaving a margin of 2.5 cm to 3.8 cm round the sheet. Inside, the detail plan should appear. A survey line should always be plotted looking north and it should be on the top of the paper.

To accommodate the plan in the middle of the paper, it is essential to draw it on a piece of tracing paper and then this should be moved on to the drawing paper. The tracing paper should be arranged in such a way that the plan is located in the middle of the drawing paper. Having ascertained the best position for the plan, the position of base line and the position of one of its extremities should be pricked through. To begin with, the base line which is the longest line should be drawn first and its length scaled. The intermediate stations on the base line are then marked with fine pencil by accurately measuring their chainage. They are lettered or numbered and are enclosed in small circle. The triangles built on the base line are then drawn

in position by describing short arcs with the ends of the base line or intermediate stations as centres and other length of the sides as radii, using beam compasses, if the radii are large. Before the point of intersection is finally marked, the line should be checked against any error. The triangles are then checked by drawing tie or check lines.

After the frame work has been plotted accurately, the offsets should be plotted using sets of squares or offset scale.

Inking in

Once the drawing of the plan is accurately done, the pencil lines should be carefully inked using fine nibs.

. Compass survey

For more accuracy both chain and compass survey can be done simulta-eously. In compass survey, the direction of the survey lines are fixed by ngular measurements so that they can be plotted from their lengths alone.

Compass survey is also known as traverse survey where the frame-work onsists of a series of connected lines, the lengths and the directions of hich are measured with a chain or tape and the angular instruments respec-vely. Here running of check lines is not necessary.

rismatic compass

The prismatic compass consists of a circular box about 12.5 - 15 cm diameter, and in the middle a magnetic needle is balanced on a hard ointed steel pivot. The needle is broad, carries on aluminium ring graduated degrees and half degrees. The graduations start from zero marked at the uth end of the needle and run clockwise so that 90° is marked in the est, 180° in the north and 270° at the east. The figures are written verted.

Diametrically opposite are sighting vane and the reflecting prism with sighting slit at the top, fixed to the box.

When the needle points north, the reading under the prism should be ro. But since the prism is placed exactly opposite the sight vane, the south d will be under the prism. Consequently, the zero graduation of the ring ıst be placed at the south end of the needle and by this bearings are tained clockwise from the north.

ethod of using prismatic compass

ntering

The compass should be centered over the station where bearing is to be ken by dropping a small stone so that it falls on the peg marking the sta-n.

velling

The compass should be levelled by eye judgement and thereafter by ling a round pencil over the surface.

w to observe bearings

Suppose it is required to observe the bearing of line AB.

i) Centre the compass over station A and level it.

ii) Turn up the vertical prism, sighting vane and raise or lower the prism until the graduations of the ring are clearly visible.

iii) Turn the compass box until the ranging rod at station B is bisected by the hair when looked through the slit above the prism.

iv) When the needle comes to rest, look through the prism and note the reading at which the hair appears to cut the image of the graduated ring, which gives the required bearing of the line AB.

Some commonly used terms

Bearing of lines

Bearing of a line is the horizontal angle which the line makes with some reference direction or meridian (true, magnetic or arbitary).

True bearing/meridian

The true or geographical meridian passing through a point on the earth's surface is the line in which the plane passing through the given point and the north and south poles, intersects the surface of earth.

Magnetic meridian

The direction indicated by a freely suspended and properly balanced magnetic needle, unaffected by local attraction is called magnetic meridian or the magnetic north and south line. In compass traverse survey, the magnetic meridian is used.

Designation of bearings

Whole circle system

In this system the bearing of a line is always measured clock wise from the north point of the reference meridian towards the line right round the circle. The angle thus measured is called whole circle bearing (W.C.B.) and it may have any value between 0° and 360°, (Fig. 3.17).

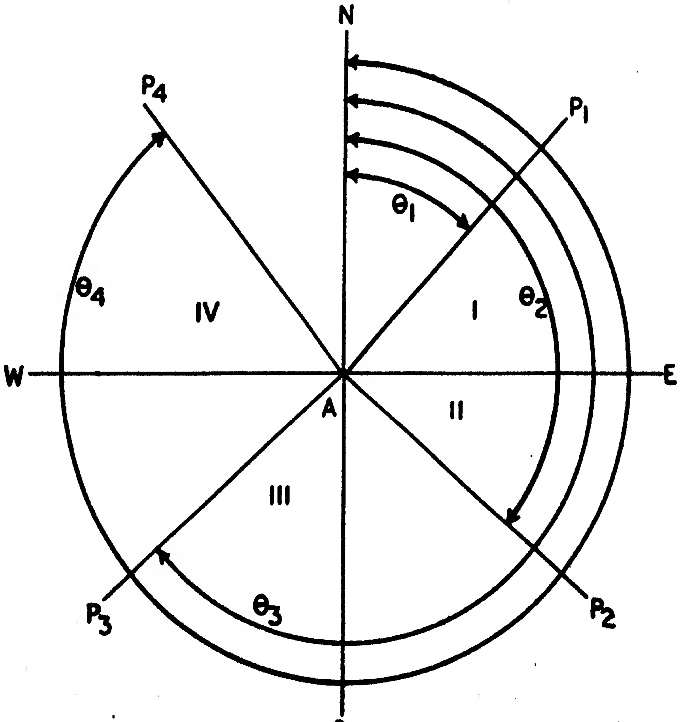


FIG. 3.17 WHOLE CIRCLE SYSTEM

In the above figure, the W.C.B. of AP_1 is θ_1, that of AP_2 is θ_2 and o on. In this system, the bearing is completely specified by the angle and he noting of cardinal points N,E,S and W is not required. The bearings ob- erved with a prismatic compass are whole circle bearings.

uadrantal system

In this system, the bearing of a line is measured clockwise or counter- ockwise direction with respect to north point or south point whichever is earer the line, towards east or west. Therefore, it is required to state the oint from which the angle is measured. Also, it is necessary to mention the rection in which the angle is measured. In order to do this, the plane around e station is divided into four quadrants by placing two lines at 90° to one other. One of these lines is the north-south (N-S) line and the other is st-west (E-W) line. The quadrants are marked as follows:

NE = 1st Quadrant
SE = 2nd Quadrant
SW = 3rd Quadrant
NW = 4th Quadrant

It is seen, that each quadrant is divided into 0°-90° and the quadrantal aring never exceeds 90°, (Fig. 3.18)

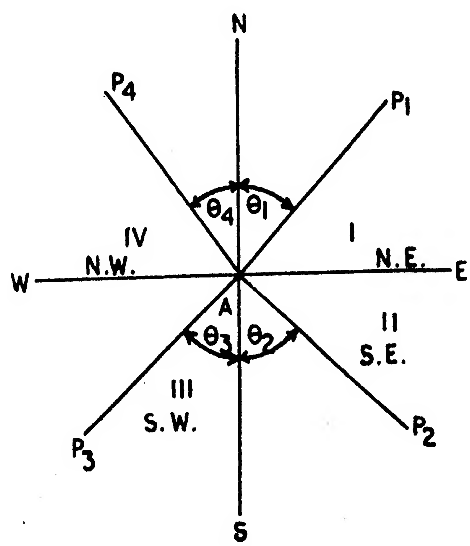


FIG.3.18 QUADRANTAL SYSTEM

There are two ways by which the bearings can be expressed. In the one the letters denoting the quadrants in which the line falls are put after numerical value of the angle. Such as the bearing of AP_1 is θ_1 NE, that P_2 is θ_2 SE and so on.

In the second notation, the letter denoting the quadrant nearest to north or south is placed before the numerical value of the bearing. Such as the bearing of AP_3 is $S\theta_3W$, that of AP_4 is $N\theta_4W$ and so on. It should be remembered that the quadrantal bearings are never stated from east or west line.

Reduced bearings

When the whole circle bearing of a line exceeds 90°, it must be reduced to the corresponding angle less than 90°. This is known as reduced bearing (R.B.). The following table need be used in reducing the whole circle bearing to reduced bearing:

Case	W.C.B. between	Rule for R.B.	Quadrant
I	0° and 90°	= W.C.B.	NE
II	90° and 180°	180° - W.C.B.	SE
III	180° and 270°	W.C.B. - 180°	SW
IV	270° and 360°	360° - W.C.B.	SW

Fore and Back bearing

Every line has two bearings. One observed at each end of the line. The bearing of a line in the direction of the progress of the survey is called the Fore Bearing (F.B.) and the bearing in the opposite direction is termed as Back Bearing (B.B.). It is important to note that both Fore Bearing and Back Bearing differ by 180°. Plus sign should be used if the Fore-Bearing is less than 180° and minus sign, if it exceeds 180°.

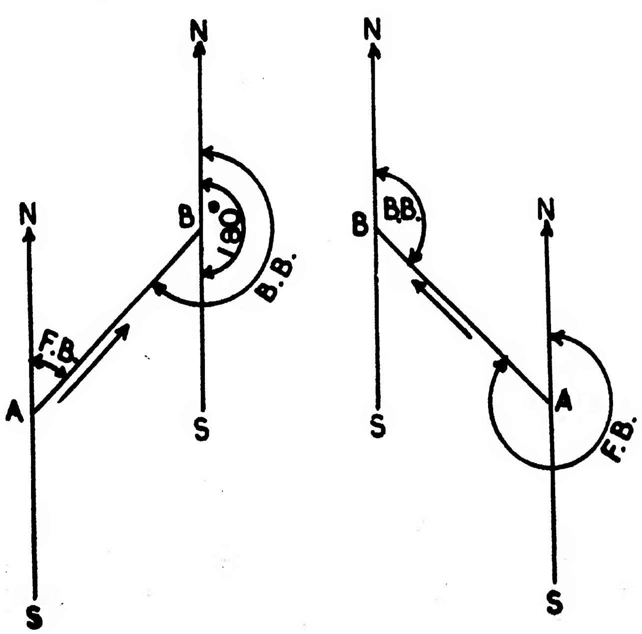


FIG.3.19 FINDING OUT FORE & BACK BEARINGS

In the above figure the bearing of A to B is the fore bearing of the line AB, and that from B to A is the back bearing of the line AB or the bearing of the line BA.

Calculation of angles from bearings

When two lines meet at a point, two angles are formed. One is the interior and the other is the exterior angle and the sum of these two angles is always 360°. Generally the smaller angle is called the interior angle, but sometimes the exterior angle could also be the smallest angle. To find out the included (interior) angle between two lines whose bearings are given, the following rules should be followed:

1) When the whole circle bearings of the lines are given

(a) When the bearings of two lines as measured from the point of intersection of the lines are given:

Rule: The smaller angle should be substracted from the greater and the difference wil give the interior angle, if this angle is less than 180°. If the difference exceeds 180°, it is the exterior angle. The interior angle can be found out by substracting the difference from 360°.

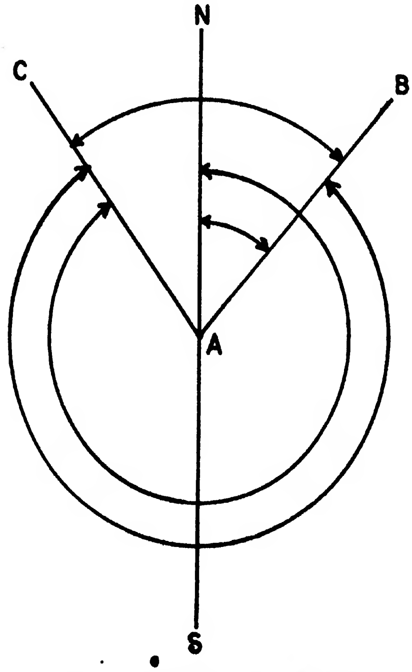


FIG.3.20 CALCULATION OF ANGLES FROM WHOLE CIRCLE BEARINGS

In Fig.3.20, if the bearings of AC and AB are given, the difference between their bearings give the exterior angle BAC and the required interior angle CAB = 360° - difference.

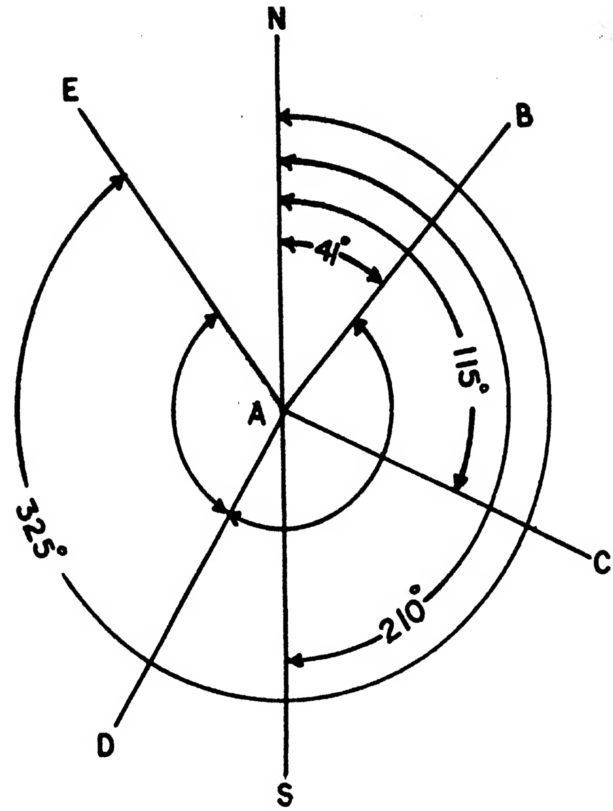


FIG.3.21 CALCULATION OF INCLUDED ANGLES FROM WHOLE CIRCLE BEARINGS

In Fig. 3.21, the observed whole circle bearings of AB, AC, AD and AE are as follows :

AB = 41°
AC = 115°
AD = 210°
AE = 325°

By applying the rule, the included angles can be calculated as follows:

$\angle$ BAC = bearing of AC - bearing of AB
= 115° - 41°
= 74°

$\angle$CAD = bearing of AD - bearing of AC
= 210° - 115°
= 95°

$\angle$DAE = bearing of AE - bearing of AD
= 325° - 210°
= 115°

BAE = bearing of AE - bearing of AB
= 325° - 41°
= 284°

EAB = 360° - 284°
= 76°

(b) When bearings of two lines are given.

In this case, express both bearings as if measured from the point where the lines meet and apply the same rule.

Refer Fig. 3.20, if the bearing of lines CA and AB are given, the bearing of AC is the back bearing of CA and is equal to forebearing (FB) of CA + 180°. Therefore, the included angle CAB will be found out by applying the above rule.

(2) When the reduced bearings of lines are given

In this situation, a straight line is drawn through the station O and term O to N as north meridian and O to S as south meridian.

Rule: If the lines are on the same side of the same meridian, the inclu ded angle = difference of the two bearings.

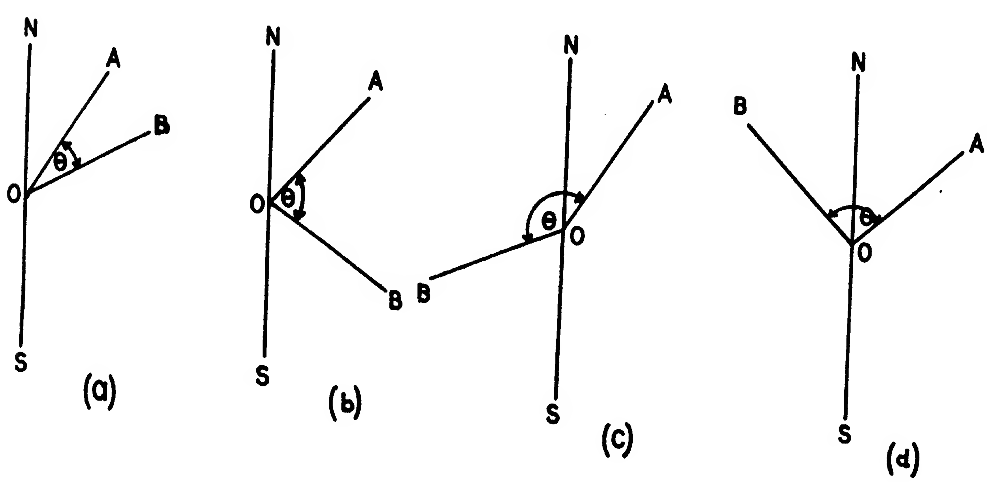


FIG.3.22 CALCULATION OF ANGLES FROM REDUCED BEARINGS

(a) AOB = difference of bearings OA and OB, (Fig. 3.22 a).

(b) If the bearings are on the same side of the different meridians *the included angle AOB =180° - sum of the two bearings, (Fig. 3.22 b).*

AOB = 180° - sum of bearing of OA and OB.

(c) If the lines are on different sides of the different meridians, *the included angle* = *180°*- difference of the two bearings,(Fig.3.22c).

BOA = 180° - *difference of the* bearings OB and OA.

(d) If the lines are on opposite sides of the same meridian the included angle = sum of the two bearings, (Fig. 3.22 d).

BOA = sum of bearings OB and OA.

Traversing with chain and compass

The compass is set up at each of the successive stations and fore and back bearings of each of the lines are observed and entered in the field book. The other related works like running of survey line, chaining, taking offsets will go on as usual as explained under chain survey.

Plotting a traverse survey

(1) By parallel meridians through each station.

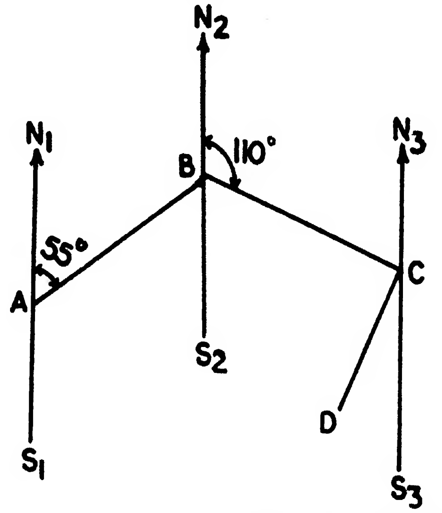


FIG. 3.23 PARALLEL MERIDIANS METHOD

Having fixed the position (Fig.3.23) of the starting station A suitably on paper, a line representing the magnetic meridian is drawn through it. The bearing of the line AB is plotted with an ordinary protractor and its length is marked off with the scale, thus fixing the position of station B. Through station B, a similar meridian is drawn, the bearing of BC is set off and its length measured with the scale. The process is repeated until all lines are drawn and the traverse is closed.

By included angles

In this method the meridian is drawn through the starting point A (Fig.3.24) and the bearing of the line AB is plotted and its length is scaled off with the scale thus fixing the position of station B. At B the included angle ABC is calculated from the bearings of AB and BC and is plotted with a protractor and the length of BC is measured off with the scale. The operation is repeated at each of succeeding stations until the traverse is closed.

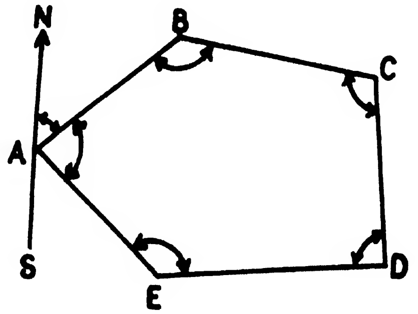


FIG. 3.24 INCLUDED ANGLES METHOD

Plane table survey

Plane tabling is a graphical method of surveying in which the field work and plotting are done simultaneously. The map is drawn in the field as the survey proceeds. The method has the advantage that the plotted work is continually under the eyes of the surveyor while he is still on the ground. Plane tabling is a method best suited for small or medium scale mapping in open or fairly open country.

The apparatus consists of:

A drawing board mounted on a tripod
Alidade (sight-vane)
U-frame with a plumb-bob
Magnetic compass
Measuring tape or a chain
Drawing paper, pencil, scale and eraser.

Advantages of plane tabling

(1) It is most suitable for preparing small scale maps
(2) It is most rapid
(3) The field book is not necessary as plotting is done in the field concurrently with the field work and hence the mistakes in booking the field notes are avoided
(4) The surveyor can compare the plotted work with the actual features of the area surveyed and thus can ascertain if it represents them properly and cannot, therefore, overlook any essential features
(5) There is no possibility of omitting the necessary measurements as the map is plotted in the field
(6) Errors of measurement and plotting may be readily detected by check lines
(7) It is particularly advantageous in magnetic areas where compass survey is not reliable
(8) It is less costly than a theodolite/dumpy level survey
(9) No great skill is required to prepare a satisfactory map

Disadvantages

(a) It is not suitable for work in a wet climate
(b) It is not intended for accurate work
(c) If the survey is to be replotted to a different scale or quantities are to be computed, it is a great inconvenience in absence of the field notes

General

The following points should be borne in mind while surveying with the plane table.

i) The table remains clamped in position while the objects are sighted. It is the alidade that is moved on the table to bisect the objects.

ii) While the sights are being taken, the alidade must be centered or pivoted on the plotted station point on the sheet i.e. the fiducial edge of the alidade must be set to the plotted station.

iii) The board is turned only when the table is to be oriented. After the table is properly oriented, the board must be clamped in position.

iv) The small letters - a,b,c, etc. - denote the points plotted on the paper to represent corresponding points A,B,C, etc. - on the ground.

Setting up the plane table

(1) The table should be set up at a convenient height for working, say, about 1m and approximately level. The legs of the tripod should be spread well apart and firmly fixed into the ground.

(2) The table should be so placed over the station on the ground that the point plotted on the paper is over the station on the ground. This is known as centering of the table. Centering can be done by using the U-Clamp. Shift the table bodily until the plumb bob hangs over the station on the ground.

The table should be levelled by adjusting the legs.

Orienting the table

The operation of keeping the table at each of the successive stations parallel to the position which it occupied at the first station is known as orientation., It is necessary when the table has to be set up at more than one station. When the table is properly oriented, the lines on the paper are parallel to the lines on the ground which they represent. There are two methods of orientating the table:

(a) By the use of the magnetic needle

To orient the table at any subsequent station, the trough compass (or circular box compass) is placed along the line representing the magnetic maridian which has been drawn on the paper at the first station, and the board is then turned until the ends of the needle are opposite the zeros of the scale. The board is then clamped in position. This method is sufficiently accurate provided there is no local attraction.

(b) Orientation by back-sighting

Suppose the table is set up over the station Q on the line PQ which has been drawn as Pq from station P. The alidade is placed along the line qp. The board is then turned until the line of sight bisects the ranging rod at P. The board is then clamped in this position. The procedure is repeated, if necessary, for other stations as well.

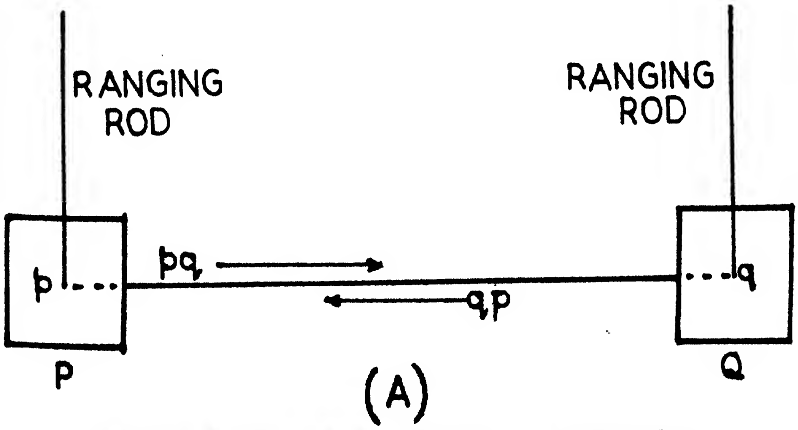


Fig. 3'25 (A). Orientation by back-sighting

There are four methods of surveying with Plane Table:

(1) Intersection
(2) Radiation
(3) Traversing
(4) Resection

Plane tabling by intersection

In this method, the point is fixed on the paper by the intersection of the rays drawn from the two instrument stations. The line joining these stations is called the base line. The method requires only the linear measurement of this base line. This method is commonly employed for locating:

i) the detail,
ii) the distant and inaccessible points,
iii) the broken boundaries,
iv) the points, which may be used subsequently as the instrument stations. It is suitable when it is difficult or impossible to measure distances between stations due to inaccessibility, (Fig. 3.25).

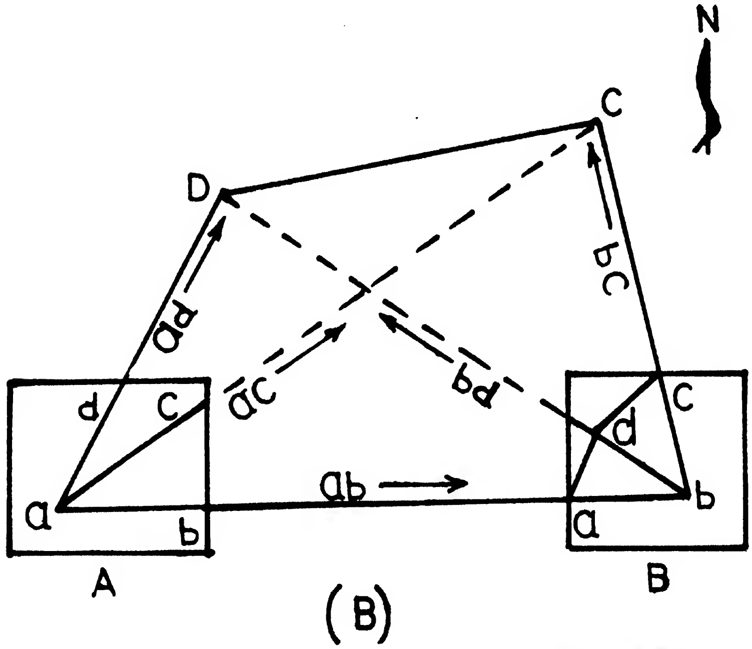


FIG.3.25(B) PLANE TABLING BY INTERSECTION METHOD

lane tabling by intersection (Fig. 3.25)

(1) Select A,B,C and D to the corner points on the boundary of the area to be surveyed.

(2) Select a base line AB so that the stations A and B commands all the points to be plotted.

(3) Chain the line AB and draw the line as ab on the sheet.

(4) Set up the plane table at station A and mark 'a' on the sheet which should be exactly above A.

(5) Keeping the alidade touching ab, adjust the board until the station is bisected. In this position, the table is oriented and ab is correctly aligned with AB.

(6) Clamp the table and mark the meridian.

(7) With the alidade touching a, move the alidade until stations C and D are sighted. Draw rays ac and ad in alignment with the ground stations C and D.

(8) Measure the distance and scale them on the sheet.

(9) Shift the plane-table to station B, centre, level and orient it by backsighting A, keeping the alidade touching ba.

(10) Draw rays bc and bd in alignment with C and D. Measure the distance and scale them off on the sheet.

(11) Point of intersection of ac and bc fixed the position of C and that of ad and bd fixed D. Similarly any number of points may be located on the plan.

Plane tabling by radiation (Fig. 3.26)

In this method, the table is fixed nearly in the centre of the area to be surveyed, so that an uninterrupted view is obtained of all the stations on the boundary. This method is generally used for:

(1) In combination with some other method.
(2) Small area, where the visibility is good.
(3) Locating details from stations established by one of the other methods.

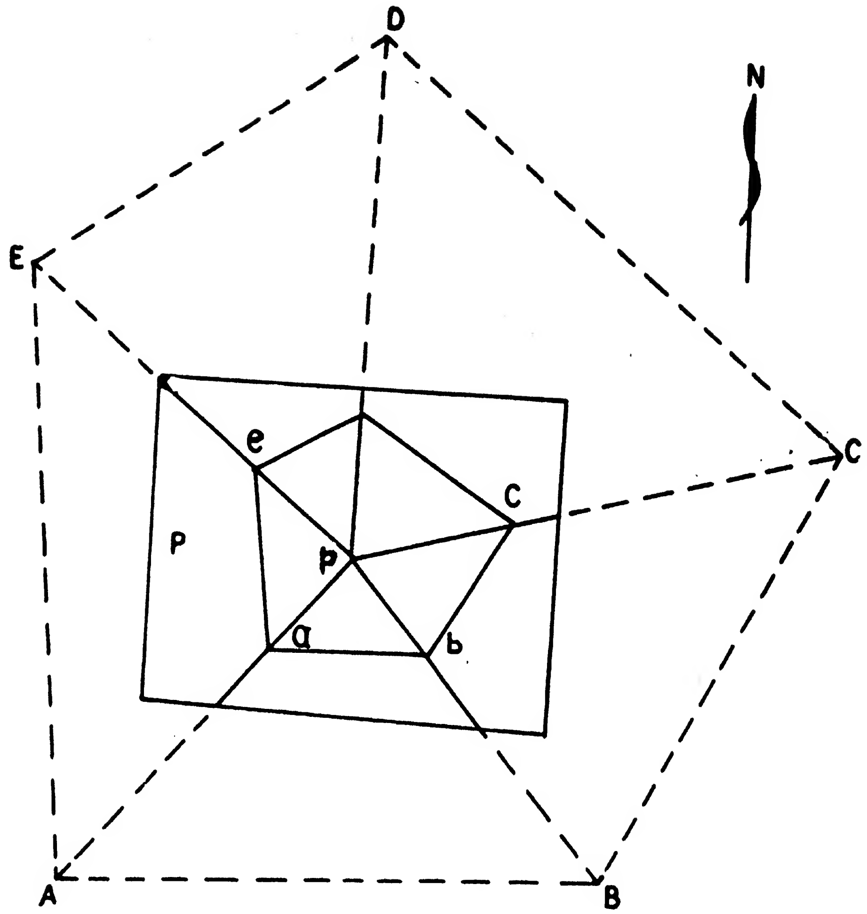


FIG.3.26 PLANE TABLING BY RADIATION METHOD

(1) Select A,B,C,D and E points on the boundary to be fixed on the plan.
(2) Set up the table at station P within that area.
(3) Select 'p' on the sheet exactly over the station P.
(4) Mark the meridian with the help of the declinator.
(5) Fix a pin at 'p' and with alidade draw rays towards A,B,C,D and E in succession.
(6) Measure the distances PA, PB, PE etc. on the ground and scale them off on the sheet as pa, pb, pc etc.
(7) Join points a,b,c,d and e, which will give the required outline abcde of the survey.

C. Level surveying

Level surveying is necessary to find out the relative heights or difference in elevation of different points or subjects on earth's surface. In level surveying, the measurements are taken in a vertical plane.

The following terms are commonly used in level survey:

Level line or plane, (Fig. 3.27)

The surface of water in a still lake can be considered as a level line or level plane. It follows the curvature of the earth's surface.

Horizontal line

A horizontal line runs tangential to the level line or plane at any place.

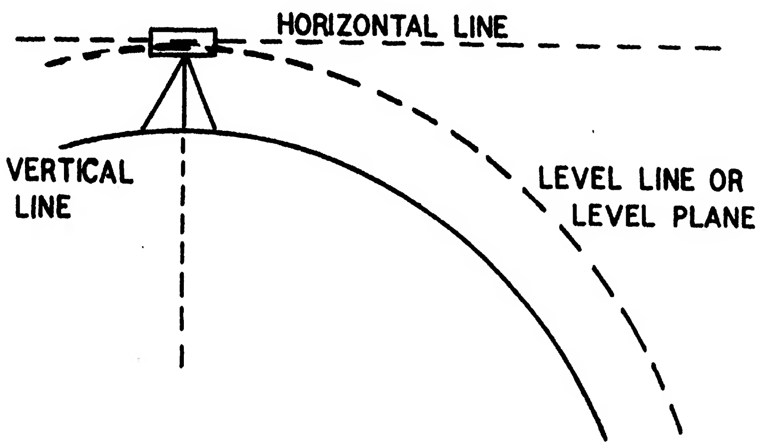


FIG.3.27 FIGURE SHOWING HORIZONTAL, VERTICAL AND LEVEL LINE

Datum line

This is an arbitrary assumed level line or surface from which elevation or vertical distances are measured. The datum line taken for India by Survey of India is the mean sea surface at Karachi where its value is assumed to be zero.

Reduced level (R.L.)

Reduced level is the relative elevation or depression of a point on earth's surface with reference to the datum line.

Bench mark (BM)

Bench mark is a field reference point of known or assumed elevation.

Line collimation, (Fig. 3.28)

Line of collimation or line of sight is a continuous line which intersects the cross hair eyesight and the object in a straight line.

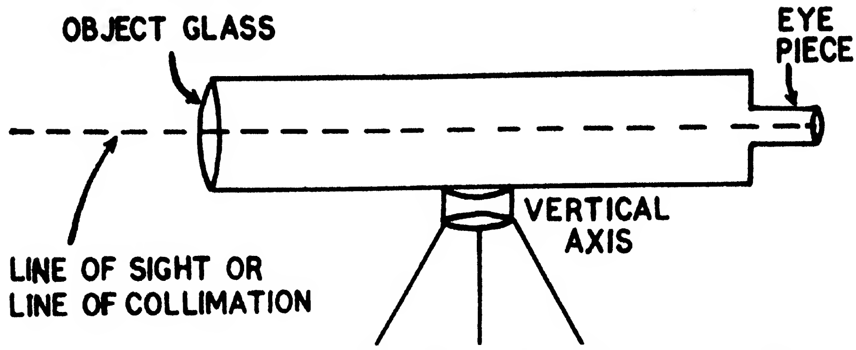


FIG.3.28 FIGURE SHOWING THE LINE OF COLLIMATION AND VERTICAL AXIS

Vertical axis

This is the centre line of the axis of rotation.

Back sight (BS)

Back sight is the first staff reading taken on a point of known elevation (i.e. on a bench mark or change point) after the levelling instrument is set up and levelled.

Foresight (FS)

Foresight is the last staff reading taken on a point whose elevation is to be determined, before the levelling instrument is shifted to a new position.

Intermediate sight (IS)

Intermediate sight is any other staff reading taken on point of unknown elevation, between the back sight and foresight, from the same set-up of the levelling instrument.

Change point (CP)

Change points are new places where the levelling instrument is shifted for convenience during the course of surveying. At change points, new height of instrument (HI) will have to be established, (Fig. 3.29).

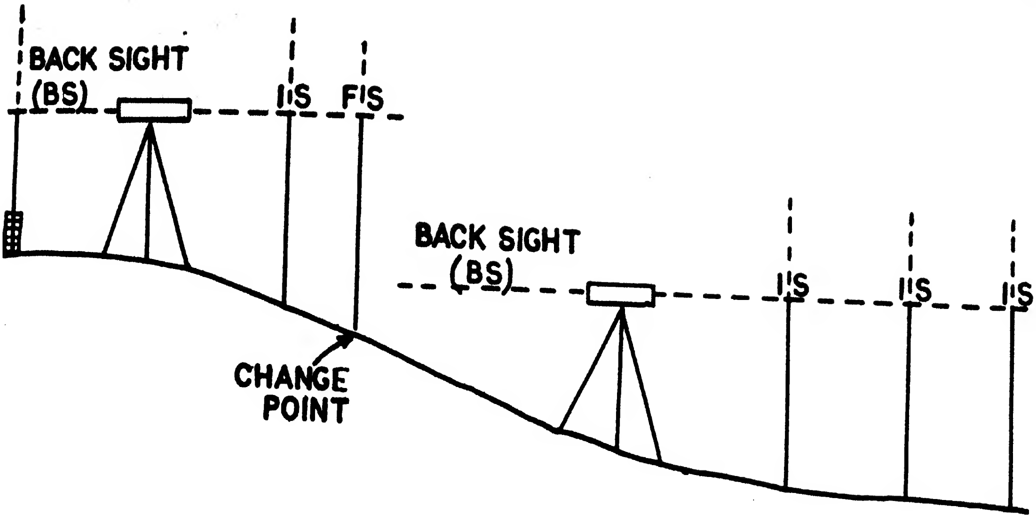


FIG.3.29. FIGURE SHOWING THE BACK SIGHT, FORESIGHT, INTERMEDIATE SIGHT AND CHANGE POINT

Height of instrument (HI)

Height of instrument is the elevation of the plane of collimation when the levelling instrument is correctly levelled.

Dumpy level

It is simple, compact and stable levelling instrument. The telescope is rigidly fixed to its supports and, therefore, can neither be rotated about its longitudinal axis nor can it be removed from its supports.

Levelling staff

There are various types of graduated staff available. The one, which we commonly use in surveying is 5 m long when fully extended. The solid top length of 1.6 m slides into the central box 1.6 m long which in turn slides into the lower or bottom box, 1.8 m long, 7.5 cm broad and 5.5 cm deep. This staff is graduated into metre, tenths and two hundredths. The figures indicating metre numeral are painted in red on the left hand side. The odd tenths of the metre are marked by black figures on the right hand side. The top of each black figure marks one-tenth of a metre in height and is exactly in line with division which it specifies. The two hundredths are indicated by the alternate white and black spaces, each measuring two hundredth of a metre. The top of a white space thus indicates an odd of two hundredths while that of a black space an even number of two hundredths.

Care of instrument

(1) Protect the instrument from impacts and vibration when being carried or transported.

(2) Keep the unwanted parts e.g. lens cap, tripod cap etc. in the instrument box when the instrument is in use.

(3) Never force the levelling screws or other movable parts.

(4) Use a survey umbrella to shade the instrument. Try to finish the field work during the morning hours as otherwise one gets difficulty with shimmer.

(5) Rub lenses only with soft tissue or cloth.

Equipment for levelling

They consist of

i) a level
ii) a levelling staff
iii) a chain or tape for measuring horizontal distances and
iv) a level field book for recording the staff reading, distances and other field notes.

SETTING UP THE LEVEL

Fixing the instrument on the tripod

Release the clamp screw of the instrument, hold the instrument in the right hand and fix it on the tripod by turning round only the lower part with the left hand. Screw the instrument firmly.

Focussing the eye-piece

Remove the lid from the object glass and hold a sheet of white paper in front of it. Now move the eye-piece in and out until the cross-hairs are distinctly seen.

Leg adjustment

Place the instrument in a desired position at a convenient height for sighting by spreading the legs well apart. Bring all the levelling screws in the centre of their run. Fix any two legs firmly on the ground by pressing them with hand and move the third leg right or left till the main bubble is approximately in the centre.

Focussing the object glass

Direct the telescope towards the staff and on looking through the eye-piece, bring the image of the staff between the two vertical hairs (or lines) of the diaphragm by lightly tapping the telescope. If a clamp and tangent screw are provided, the same should be used. Now adjust the objective by turning the focussing screw until the parallax is eliminated. The parallax is completely eliminated when there is no change in the staff reading when the eye is moving up and down.

Levelling up

Place the telescope parallel to a pair of foot screws and bring the bubble to the centre of its run turning these screws either both inwards or both outwards. Turn the telescope back to its original position without reversing the eye-piece and object glass ends. Again bring the bubble to the centre of its run and repeat these operations until the bubble remains in the centre of its run in both positions. Now, if the instrument is in adjustment, the bubble will traverse(i.e. remain central) for all directions of the telescope.

Reading the staff

Care should be taken in holding the staff truly vertical. For doing this, the staff man stands behind the staff, heels together with the heel of the staff between his toes and holds it between the palms of his hands at the height of his face. The staff should be swayed back and forth till the minimum reading is obtained.

While taking reading bring the staff between the two vertical hairs, and always use the portion of the horizontal cross-hair between them in reading the staff as the horizontal cross-hair may be slightly inclined. You should also keep watch whether the bubble is at centre or not. If not, centre it by using one of the foot screws most nearly in line with the telescope and note the reading at which the hrizontal cross-hair appears to cut the staff. First note the red figure, then the black figure and finally count the spaces. Record the reading.

The principle, on which the process of levelling is based, is shown here. The hatched line represents the section of a piece of ground, (Fig. 3.30).

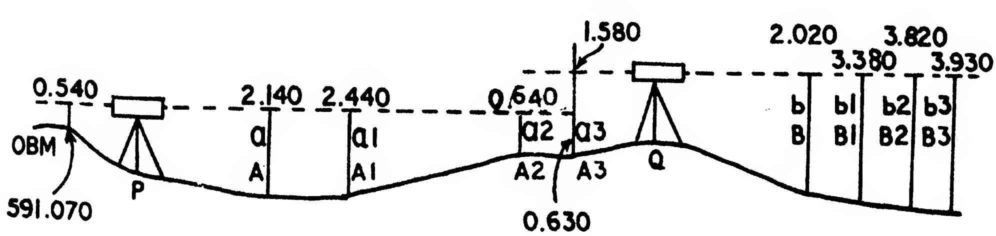


FIG.3.30 FIGURE SHOWING THE PROCEDURE FOR TAKING LEVELS

The level is set up in such a position that staff readings at A, A_1, A_2 and so on can be taken whose levels are to be determined, the horizontal distance $A-A_1, A_2$ etc. being found at the same time by chain or tape on the ground.

The straight line $a-a_1-a_2$ etc. is the line of collimation or line of sight of the instrument - which in case of a level is truly horizontal when the instrument is in perfect adjustment and properly set up at the point P. The staff readings A, A_1 etc. are the vertical distances of the points whose levels below the plane of collimation are required or the plane described in space when the telescope of the level is rotated about its vertical axis. The staff is held at points A, A_1, A_2 and so on and the readings obtained with the level are recorded in a level book. On reaching the point A_3, the line b, b_1, b_2 etc represent the new line of collimation and the work of reading the staff continues from this second position of the level. This change of position is also made when the line of collimation is above the top or below the foot of the staff.

System of booking levels

There are two systems of booking a series of staff readings in a level book:

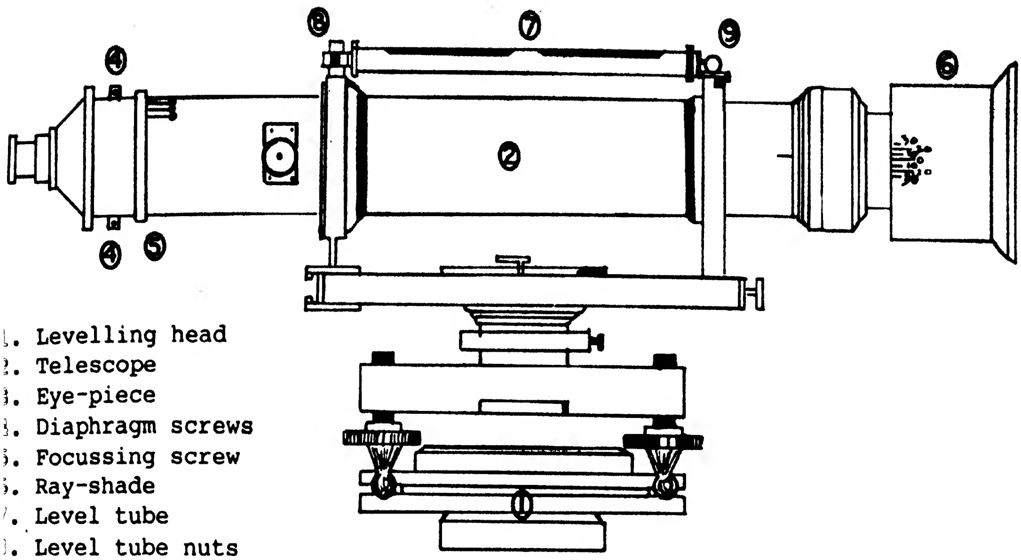
(i) The Height of Instrument or height of collimation system; and
(ii) the Rise and Fall system.

Height of instrument or height of collimation system

It consists of finding the elevation of the plane of collimation (HI) for every set up of the instrument, and then obtaining the reduced levels of points with reference to the respective plane of collimation.

This table represents a page of a level book ruled for this method of booking and the staff readings in the above figure have been used to fill in the different columns. The method of calculation of the reduced levels of the points along the section is as follows:

Station	Distance in metre	Back sight (BS)	Inter-mediate (IS)	Fore sight	Height of instru-ment(HI)	Reduced level	Remark
		0.540			591.610	591.070	ON OBM 591.070
A	0		2.140			589.470	
A_1	10		2.440			589.170	
A_2	20		0.640			590.970	
A_3	30	1.580		0.630	592.560	590.980	(CP)Change point
B	40		2.020			590.540	
B_1	50		3.380			589.180	
B_2	60		3.820			588.740	
B_3	70			3.930		588.630	
		2.120		4.560		591.070	- 588.630
	Checks :	4.560	- 2.120 =	2.440		= 2.440	



1. Levelling head
2. Telescope
3. Eye-piece
4. Diaphragm screws
5. Focussing screw
6. Ray-shade
7. Level tube
8. Level tube nuts
9. Cross bubble tube

FIG.3.31 FIGURE SHOWING THE PARTS OF A DUMPY LEVEL

The first reading taken on OBM 591.070 is always entered as a back ight (0.540 in this case) and all the subsequent readings, excepting the last, or any particular set up of the level are entered as intermediate sights (IS); he last reading being entered as a foresight (0.630 in this case). At this oint the staff holder stays still; such a point is known as a change point r turning point (CP in this case) and the surveyor moves ahead with his evel. Now he sets up the level in the second position (Q) from where he can ee conveniently the staff when held on the next series of points to be evelled. After levelling the instrument, he reads the staff (at point A3) gain and enters the reading (1.580 in this case) as a back sight on the same ne in the level book. Thereafter, he proceeds to read the next sights shown the intermediate column (2.020, 3.380 & 3.820 in this case) and finishes ith the next reading (3.930 in this case) which is to be booked in the foresight column. The position of the levelling instrument is changed again leaving the staff in the same position if further area is required to be covered.

For finding out the reduced levels of the points along the section, the rst back sight (0.540) is added to 591.070, the observed bench mark, this ves the height of the line of sight or line of collimation above datum 91.070 + 0.540 = 591.610). This is (591.610) - the height of the instrument

and is entered in that column (HI) in the level book as shown in the table. After this, each subsequent staff reading is subtracted in turn from the height of the instrument 591.610. Therefore, the reduced level at A is 591.610-2.140 = 589.470, reduced level at A_1 is 591.610-2.440 = 589.170 and so on. The foresight at A_3 is similarly treated and the reduced level is 591.610-0.630 = 590.980.

At the change point the new height of the line of sight or line of collimation is to be found out (as the instrument has been re-set at a different level than the previous position). This is done by adding the reduced level at A_3 and the back sight at the same position i.e. 590.980 + 1.580 = 592.560 and entered in HI column. The succeeding readings are again subtracted from this new height of the instrument to give the reduced levels of the remaining points on which levels are taken.

The results obtained so far should be checked by adding up the back sights, and then adding up the fore sights and subtracting the lesser of the sums from the greater. The difference thus obtained should be exactly the same as the difference of the first and the last reduced levels. In the example, the sum of the fore sights = 4.560 and sum of back sights = 2.120; the difference of these sums 4.560 - 2.120 = 2.440. The difference between first and last reduced levels = 591.070 - 588-630 = 2.440.

Rise and fall system of booking

In this system, the ruling of the pages of level book is the same as in the case of the other method described earlier, except that rise and fall column take the place of height of instrument (HI) column.

The entries and booking of the staff readings are exactly the same as for the height of collimation method, but the first reading being less than the second reading is substracted from it i.e. 2.140 - 0.540 = 1.600. Since the second reading is greater than the first one, the foot of the staff must be lower at point A than at OBM. Thus the figure of 1.600 is a fall and is entered in the 'Fall' column of the level book. This process is continued down the page, each reading is subtracted from the one next below and if this reading is bigger than the previous one, the difference will come in the 'Fall' column and if smaller than it, in the 'rise' column. Now the reading at point A_2(IS) is more than at point A_3(FS) and the difference 0.640 - 0.630 = 0.010 will be rise. Therefore, the back sight (BS) reading at A_3 should be deducted from reading at B_1(IS), the reading at B_1(IS)be subtracted from reading at B_2(IS) and so on down the page.

Table 3.2 The rise and fall method of booking

(Using the staff reading given under collimation method)

	Distance in metre	Back-sight (BS)	Inter-mediate sight (IS)	Fore-sight (FS)	Rise (+)	Full (-)	Reduced level	Remark
		0.540					591.070	OBM = 591.070
A	0		2.140			1.600	589.470	
A_1	10		2.440			0.300	589.170	
A_2	20		0.640		1.800		590.970	
A_3	30	1.580		0.630	0.010		590.980	(CP)Change point
	40		2.020			0.440	590.540	
$_1$	50		3.380			1.360	589.180	
$_2$	60		3.820			0.440	588.740	
$_3$	70			3.930		0.110	588.630	
		2.120		4.560	1.810	4.250		

Checks:
4.560 - 2.120 = 2.440
4.250 - 1.810 = 2.440
591.070 - 588.630 = 2.440

The reduced levels are found by adding successively all rises and sub-racting successively all falls from the previous RL. Thus reduced level at oint A = RL of OBM 591.070 - fall from OBM to point A_2 is reached, the ise from A1 to A_2 is added with the previous RL i.e. 589.170 + 1.800 = 90.970 which is RL of point A_2.

omparison of the two system

The collimation method is less tedious, more rapid and involves less alculations. However, mistakes made in reduction of levels of the inter-nediate points remain undetected, while in the rise and fall system, there s a complete check on each of the intermediate reductions. The first system s generally used in profile levelling and setting out levels for constructional ork, while the second one is prepared for differential levelling, check leve-ing and other important work.

ERRORS IN LEVELLING

Instrumental

The instrument must be in perfect adjustment. The essential conditions are that the line of collimation must be paralled to the bubble line and both of them must be at right angles to the vertical axis. After the instrument is set up, if during every reading the bubble is to be brought in the centre, then permanent adjustment will have to be made. Till the above is not done, the position of the staff at change points should be so selected that its distance from the instrument is exactly or at least very nearly equal to that where the previous back sight was taken.

Errors in manipulation

While taking back or foresight, if the bubble moves out of centre, then bring it in the centre by turning the screw or screws which are nearest in line with the axis of the telescope. Once the adjustment is done do not touch the legs of the level. The error increases with the increase in the staff reading and is maximum when the reading approaches the top.

Errors in sighting

The common error is due to parallax. There will be no parallax so long the focus of the eye-piece and that of the cross hairs of the diaphragm coincides.

Errors due to the settlement of level or staff

If one or two legs settle down after setting up of level either by their own weight or in soft ground the bubble will get disturbed. If the staff settles down it will remain undetected. The staff should, therefore, be placed on a firm ground when the position of the instrument is changed.

Errors due to natural causes

This may be due to curvature of the earth, refraction or effect of strong wind. The first two are not important for ordinary levelling operation and correction can be applied. But when the wind is strong, levelling should be stopped. If the rays of sun strike the object glass it is difficult to read the staff. In such cases survey umbrella should be used.

During summer after 10 O' clock in the morning, the staff facing the sun cannot be read from distance and at that time it should be held nearer to the level.

Bubble correction

If the bubble moves out of the central position i.e it does not traverse, bring the telescope on the first pair of foot screws just to see whether it returns to the centre, then turn the telescope to far end and note its departure from one-half of this departure i.e. n divisions by turning the capstan-headed nuts at one end of the tube which connect the bubble tube to the telescope and the other half by turning the foot screws and bring the bubble to the centre. One or two trials may be required.

paration of countour map

For this purpose the levels should be taken on a grid system spaced at ance consistant with accuracy. The reduced levels of those points should, efore, be recorded on the base map. It is essential to insist that the sur-or takes levels on the grid lines whenever there is a distinct change in topography so that the level map is accurate representation of the topo-phy.

4

BEHAVIOUR AND GROWTH OF TEA PLANTS IN RELATION TO SOIL MOISTURE

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Introduction

Water from the soil is absorbed through feeder roots and is translocated through conducting vessels to the leaves, which are the centre of metabolic activities. Stomatal pores are distributed on the under surface of leaves which help in gas exchange. Water vapor escapes to the atmosphere through the stomatal pores. Therefore, soil–water–plant relationship is a continuum. Alongwith the water, mineral nutrients are also absorbed and enter the plant cells. The deficit in plant water is caused due to the transpirational loss through the cuticle and stomata, whereas moisture stress in soil is caused by evaporation. The water status of plant is never in equilibrium with that of soil. Two types of water stress are encountered in tea - drought due to deficit and waterlogging due to excess water. Plant response to water stress can be studied for whole plant as well as at the cellular level.

Water deficit

Water deficit occurs in the tissues of transpiring plants. When there is enough moisture in the soil, due to gradient between soil water and plant water content, water is absorbed and translocated to make up the deficit. If the transpirational loss exceeds absorption, the moisture stress sets in and the plants start wilting. Wilting starts first in tender leaves and shoots on the plucking table of the tea bush. The lower leaves and shaded shoots below the plucking table are less affected.Continued water deficit restricts leaf expansion and delays bud break, resulting in smaller leaves and less number of pluckable shoots.

Water deficit sets off series of reactions in the leaves. The first action is the loss of turgidity in the tissues. In response to reduced turgor, the stomatal pores close in an attempt to conserve moisture, thereby reducing the transpirational loss of CO_2 intake. Due to stomatal closure, photosynthetic rate goes down leading to reduced assimilates available for plant function. As the turgidity is reduced coupled with lack of assimilates, the translocation of assimilates to other parts i.e. the sinks (bud) is reduced. Due to the paucity of metabolite supply, the bud break and leaf expansion are retarded, which ultimately reflect on the poor crop. If the deficit is of short duration the plants recover and make up the loss in yield. If the deficit is of prolonged nature, the loss is not made up and future yield is also affected.

Water deficit may be caused due to environmental condition like high ambient temperature due to direct solar radiation or high winds. These are short lived and remedial measures like good shade and windbreaks (shelter belts) can reduce the impact. Water deficit can also be overcome by timely

rigation. These ameliorative steps against water deficit reflect in ultimate creased productivity of the tea bushes.

Potential difference between uptake and transpiration determines the urvival of the plant. Transpiration loss slows down when soil moisture conent drops down to 40% of available moisture. During post planting and post runing of tea bush, there will be reduction in transpiration rate proportional o the amount of soil surface exposed to sun. The clones differ due to their ifference of stomatal response during water stress. Rooting depth is another eterminant which varies with soil and water. In dry soils, water movement restricted. Roots must obtain water by extending deep into the moist soil yers. In this respect, the alternation of growth phases between roots and hoots are worth noting. There is cessation of root elongation following pruing of tea bush.

ellular level response to water deficit

Growth or streaming of protoplasm is the criteria for life. At low vater content of cells, protoplasm undergoes desiccation. Desiccated protolasm retains viability. Sugars and proteins can offer protection to enzymes ndergoing dehydration. Due to the dehydration of protoplasm, the organelles hloroplasts, responsible for photosynthesis and the intracellular enzymes inside are esiccated, ultimately affecting the rate of photosynthesis and assimilation of hotosynthates. Inactivation of enzymes during dehydration is due to intra/iner molecular structural changes. Further water deficits of intact cells lead o release or to activate the degradative enzymes. Water deficit thus affects he cells either through direct damage or through interaction or conformaional changes. Photosynthesis responds to desiccation and rehydration before hanges to transpiration. The following are the cellular level changes due to vater deficit:

(1) reduction in photosynthesis,
(2) closure of stomates,
(3) reduction in chloroplast *(electron transport) activity,
(4) reduced dark respiration,
(5) reduced cell expansion and leaf growth.

Stomatal closure and restriction of CO_2 diffusion may account for loss f photosynthetic activity. Decreased chloroplast activity is the cause of epressed photosynthesis especially the light reaction. Decreased development f leaf area due to water deficit results in decreased photosynthesis ecrease in leaf area is the earliest sign of water deficit. Leaf senescence accelerated resulting in irreversible loss of photosynthetic surface. Loss n leaf area coupled with photosynthesis rate causes potential crop reduction. Vater deficiencies therefore, decrease yield by decreasing photosynthates ccumulated during the season. Figure 4.1 shows three different clonal plants f tea in wilted stage due to moisture stress.

FIG. 4.1. EFFECT OF DROUGHT ON 3 DIFFERENT TEA CLONES

FIG. 4.2 EFFECT OF WATERLOGGING ON TEA SHOOT

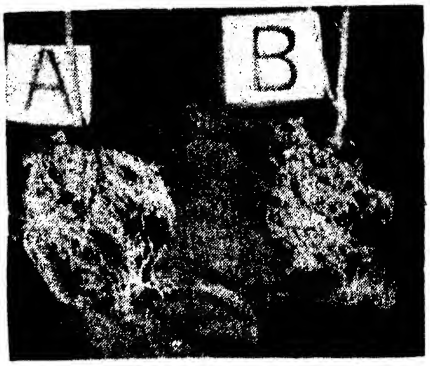

FIG 4.3 EFFECT OF WATERLOGGING ON YOUNG TEA ROOTS
(A) NORMAL (B) WATERLOGGED

Leaf shedding

During prolonged water deficit, as a protective and conservancy mechanism, the plants shed their leaves to minimise the transpiration loss. Leaf fall is hastened by formation of abscission layer. Sometimes, leaf fall starts after rehydration. Formation of abscisic acid and ethylene are implicated in leaf shedding. Plant responses to water deficit may be summed up as below:

(1) translocation of assimilates reduced,
(2) reduction in photosynthesis,
(3) reduction in growth,
(4) reduction in sink, and
(5) reduction in leaf area.

Both leaf expansion and senescence are sensitive to water deficit.

Waterlogging

Waterlogging during rainy season is a common feature in tea soils. At times plants are also submerged upto ground level for prolonged duration. The primary cause of suffering of plants due to waterlogging is due to lack of aeration. Impeded respiration due to paucity of oxygen will suffocate the roots which retards the absorption of nutrients and synthesis of vital hormones like cytokinin and gibberellic acid. Prolonged waterlogging triggers the release of ethylene gas which suppresses the growth and accelerates leaf fall through abscission.

Saturation of soil for extended periods leads to a number of sequential physiological disturbances in tea plants as follows:

(1) reduced absorption,
(2) leaf water deficits,
(3) reduced mineral uptake,
(4) leaf epinasty,
(5) stem thickening,
(6) callus and adventitious roots,
(7) leaf senescence, and
(8) leaf abscission usually with lower leaves.

Causes of injury due to waterlogging

Principal causes of injury due to waterlogging are:

(1) decrease in soil oxygen,
(2) increase in CO_2,
(3) pronounced water stress, and
(4) wilting of leaves.

Continued deficit of aeration causes injury and death of cells. Both absorption and translocation of nutrients are hindered due to lack of permeability of root membrances and plugging of xylem vassels with tyloses. Ultimately the roots are degenerated and destroyed.

Waterlogging reduces gibberellin level in shoots. Hence waterlogged plants respond better than unflooded plants to gibberellins. Chlorosis of

lower leaves in flooded plants is attributed to decrease in cytokinin synthesis in roots. Ethylene has the central role in inducing the injury and eventual leaf shedding. The effect of waterlogging on tea shoots and roots are shown in Fig. 4.2 and 4.3 respectively.

Measurement of shoot water status

Shoot water status is measured based on:

(1) relative water content, and
(2) pressure chamber.

Water content of shoots in day time varies between 85-95%. The fluctuation is subject to environmental variations. The most reliable and commonly used technique is Scholander Pressure Chamber technique which measures the water tension in the xylem, known as turgidity. The shoot water potential fluctuates between -5 to -15 bars depending on the soil moisture deficit.

Sampling and the technique of measuring shoot water status using pressure chamber has been standardised and the Tocklai Cultivars had been evaluated for drought tolerance.

Distribution of stomates, response of stomates to drought in terms of stomatal resistance to transpiration, accumulation of proline etc. had been evaluated by TRA to use as a parameter for screening. Stomatal resistance and proline accumulation are positively correlated with the drought tolerance of cultivars.

Water stress and productivity

Stresses that reduce transpiration also reduce dry matter production. Lower the water content in leaves, lesser is the rate of photosynthesis. Tea, being a C3 plant, is more sensitive to shoot water potential influenced by transpiration.

Tolerance allows plants to survive the stress by slowing down both dry matter accumulation and transpiration. Some amount of energy is spent in the adaptation as well. Hence, a drought tolerant plant may not be as productive as a plant growing in optimal conditions. Temporary ameliorative steps to overcome drought especially in young tea through use of growth regulators - antitranspirants are being attempted. Potash foliar spray during dry months against drought is the recommended practice. However the long **lasting permanent** solution lies in evaluation of tolerant plants through breeding and improved management. An ideal plant envisaged should be of high water use efficiency, higher productivity and drought tolerant responding favourably to higher inputs.

Root growth

The most affected part of the plant under waterlogged condition is root. The roots decay and cannot absorb the nutrients. In waterlogged soil, there is accumulation of hydrogen sulphide. Presence of even a trace of hydrogen sulphide is very toxic and can kill the plants. Roots have the ability to extract nutrients when in contact with soil crumbs. Roots can also take

ip immobile nutrients such as phosphate by establishing direct contact. Under waterlogged condition, because of collapse of soil crumbs and degeneration of root system, roots not only fail to establish such direct contacts but also cannot take up the required amount of nutrients from the soil solution.

Experimental Results

A high watertable during the rains and stiff, compacted sub-soils are considered to be the main reasons for poor and shallow development of roots in many tea areas in the plains of N.E. India. Both these conditions interfere severely with root aeration, restricting root growth to the surface layers of soil where air is more readily accessible. Distribution of root system of tea bush is shown in Fig. 4.4.

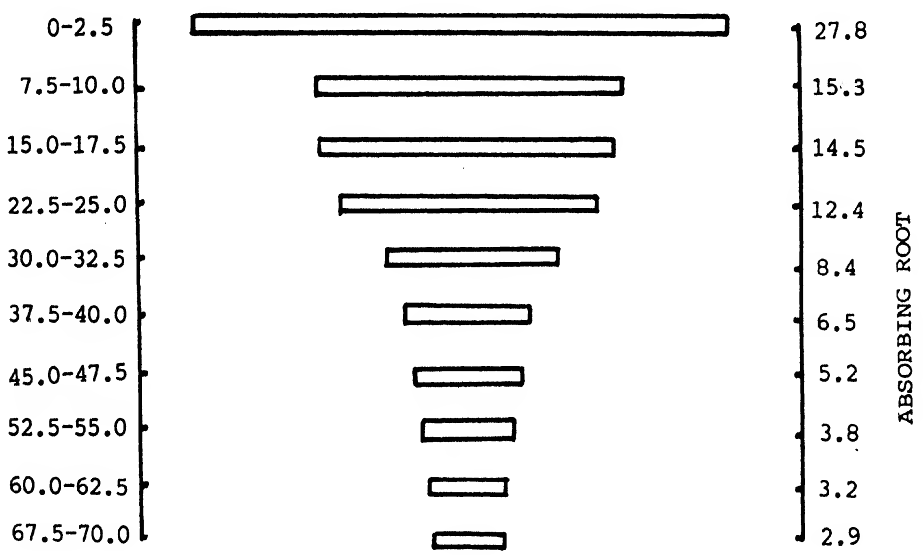

FIG. 4.4. DISTRIBUTION PATTERN OF ROOT SYSTEM

Thus, the whole problem of increasing root and therefore, top growth of tea bushes revolves round improved aeration and drainage of soil. So far, much importance has been placed by the industry to the management of the aerial part of the tea bushes. Attention to the top alone would not raise the yield of the tea bushes to the desired levels.

It has been commonly observed that:

i) tea bushes in plains of N.E. India are shallow rooting,

ii) there is an intimate relationship between growth of the **aerial part** and the root of a tea plant,

iii) without increasing the volume of roots, it is not possible to increase the top growth beyond a certain limit and hence yield will be limited.

iv) making due allowances for clonal and jat differences, the root growth can only be improved by improving soil aeration and preventing waterlogging.

Photosynthesis

In an experiment conducted on six month old tea seedlings grown under ideal conditions in a glass house, the following treatments were studied:

Group 1 Control - left in normally watered state;
Group 2 Plants placed up to base of their stems in standing water (waterlogged series).
Group 3 Plants not watered at all (drought series).

At frequent intervals, plants from all the three groups were taken into the laboratory and by using infra-red gas analysis technique, photosynthesis was determined. The rate of carbondioxide uptake, which is a measure of photosynthetic activity, is given in Table 4.1.

Table 4.1 Rate of CO_2 uptake

Treatments	Rate of CO_2 uptake, ppm
Normal plants	21 - 43
Waterlogged plants	0 - 5
Drought plants	1 - 6

The above results are extracted as typical from many determinations during the experimentation and quite a staggering effects of waterlogging and drought on the growth of the plants are clearly seen. When the droughted plants were watered they responded and regained growth, but the waterlogged plants on draining excess water were slow to recover.

Transpiration loss

The results from our Physiological studies on transpiration loss by plants that are waterlogged and plants grown at field capacity moisture are shown in Table 4.2

Table 4.2 : Transpiration loss by tea plants under waterlogged and control conditions

Treatment	moisture loss per leaf per day, mg
Waterlogged plants	220.7
Control; plants grown at F.C. moisture	354.8

Inspite of higher relative turgor of the waterlogged leaf, there was marked reduction in transpiration rate. Further, the waterlogged plants showed symptoms similar to wilting even at field capacity level. This is because the roots were incapable of drawing water as the roots were found to turn black and got decomposed.

eactions of tea to various soil water supply

Experiments were carried out with clones to find the effect of various ooding levels and no moisture supply to tea. The clones included were broad af Assam type, hybrid and extreme china (clones TV-18, TV1 and TV7 res- ɛctively).

The treatments included were:

T_1 = Field capacity moisture
T_2 = No moisture replenishment
T_3 = Half root zone submerged
T_4 = Full rootzone submerged
T_5 = Plants half submerged
T_6 = Plants fully submerged.

$_1$ (Field capacity moisture)

The plants were weighed at intervals and the réquired water was added ɔ maintain moisture in rootzone at field capacity level till the end of the xperiment.

$_2$ (No moisture replenishment)

No moisture replenishment was made and the soil in the rootzone was llowed to dry till the plants showed signs of wilting.

$_3$, T_4, T_5, T_6 (Treatments receiving various degrees of waterlogging)

One plant of each clone from each treatment was taken out every day ll the end of the experiment and kept under shade to drain off excess ater.

The results were as follows:

i) Clones did not differ between themselves as far as their reaction to waterlogging is concerned.

ii) Plants kept at field capacity moisture (T_1) showed uninterrupted growth throughout.

iii) Plants, which received no moisture replenishment (T_2) showed signs of wilting when the soil moisture level dropped down to 5.7%, but revived when watering was done. They showed permanent signs of wilting when soil moisture dropped to 4.2% and could not be revi- ved by watering and the plants died.

iv) Half rootzone submerged (T_3) plants upto two weeks did not show any noticeable effect, when allowed to drain excess water. Beyond two weeks upto end of three months period when the experiment was terminated, the plants showed signs of distress of varying degrees depending on the length of submergence period but all sur- vived on draining excess water from rootzone.

It was observed that new root growth started from above the zone of submergence and the plants started growing again.

v) *Full rootzone (T_4) and half submerged plants (T_5) showed* signs of distress in about five days time. But survived on draining rootzone moisture, up to 4th week of submergence in a moribund state. Beyond 4th week, all the plants died and roots decayed giving off hydrogen sulphide (rotten egg smell).

vi) In fully submerged plants (T_6) defoliation and blackening of stem started in two days time but survived in a moribund state on draining rootzone water upto two weeks of submergence. Beyond two weeks of submergence, the plants could not be revived on draining water from rootzone.

Results of this experiment are summarised in Table 4.3.

Table 4.3 Summarised results of different levels of moisture treatment

Treatments	Condition of growth	Whether plants can be revived on adding water or draining excess water as the case may be	Rate of recovery	Any other feature
T_1 (Field capacity moisture)	Good growth all throughout			
T_2 (No moisture replacement)	Temporary wilting at soil moisture 5.7%	Yes	Fairly rapid	Root system alright
	Permanent wilting at soil moisture 4.2%.		Plants died	Dead roots attached to plants
T_3 (½ rootzone submerged)	No symptom up to 2 weeks	Yes, upto 3 months	Slow	New roots developed
T_4 (Full rootzone submer merged)	Sign of distress in 5 days	Yes, upto 4th week	Very slow	H_2S present
T_5 (½ plant submerged)	Sign of distress in 5 days	Yes, upto 4th week	very slow	H_2S present
T_6 (Full plant submerged)	Sign of distress in 2 days	Yes, upto 2nd week	very very slow	H_2S present

ct of water table on growth of tea

To study the growth and nutrient uptake by tea plants in association th water table at depths 45, 90 and 135 cm from the soil surface, tanks de of G.I. sheets were installed. The arrangement comprises of an inner k of 1.5 m x 1.5 m x 1.5 m with wire mesh at the bottom, placed within outer tank of 1.8 m x 1.8 m x 1.8 m. The outer tank was provided with tlet at desired depth from the surface to allow maintenance of watertable inner tanks at 45, 90 and 135 cm from the surface. The inner tanks were ed with soil in the natural sequence occurring in the field and allowed to tle down for about a year before starting the experiment.

When the soil settled down in tanks, eighteen month old clonal plants 1 and S3A/3 were planted at spacing of 25 cm x 21 cm.

The growth was poor in 45 cm but growth at 90 cm and 135 cm was ally good at the beginning. But one year after planting there was drought the beginning of the year and the plants in 135 cm tank suffered very ily and could not recover for next few years.

eld

Relationship between yield and depth of watertable is shown in Fig.

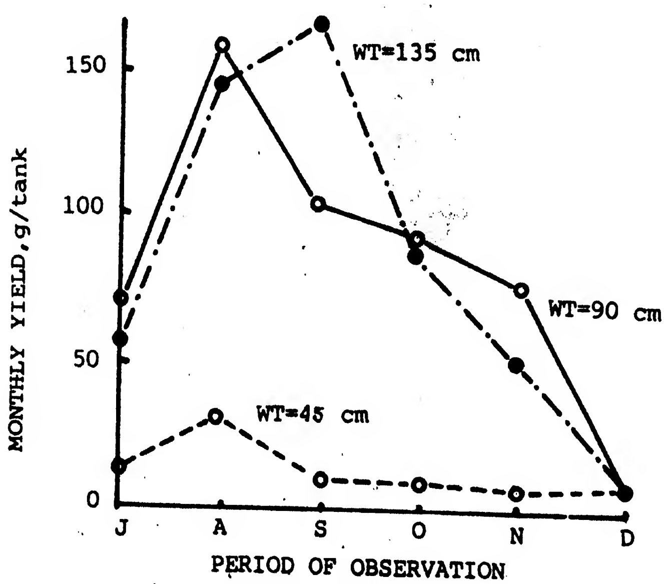

FIG. 4.5. RELATIONSHIP BETWEEN TEA YIELD & DEPTH OF WATER TABLE

It is clearly seen that when watertable was kept at 45 cm from sure, the yield trailed off very considerably as compared to the bushes grown h water table at 90 cm and 135 cm from the surface. Plants grown at er table fixed at 45 cm from the surface had to be replaced every year most of the plants died or existed in moribund condition due to watergging.

Results of survey on good and bad drainage

A survey on the effect of drainage on yield and response to fertiliser was carried out by TRA in areas comprising of Dooars and Terai. All the 112 member estates of Dooars and Terai were included in this survey. Effect of drainage status on yield is shown in Fig. 4.6.

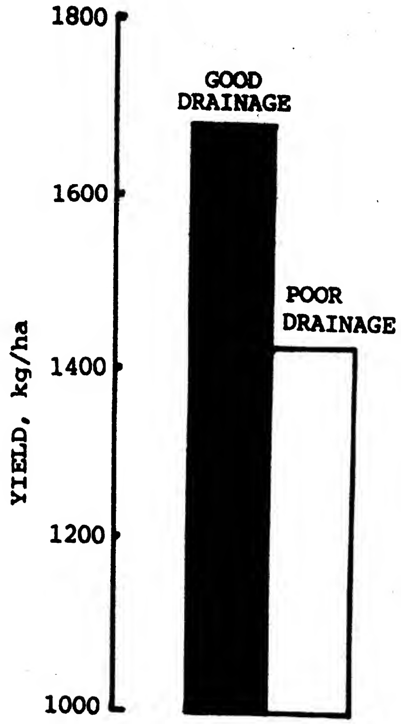

FIG. 4.6. EFFECT OF DRAINAGE ON YIELD

The overall yield increase due to good drainage was estimated as 18%. It may be noted here that under ideal drainage conditions, increase in yield could be as high as 50% in some areas.

Effect of nitrogen manuring on yield under good and poor drainage condition is shown in Fig. 4.7.

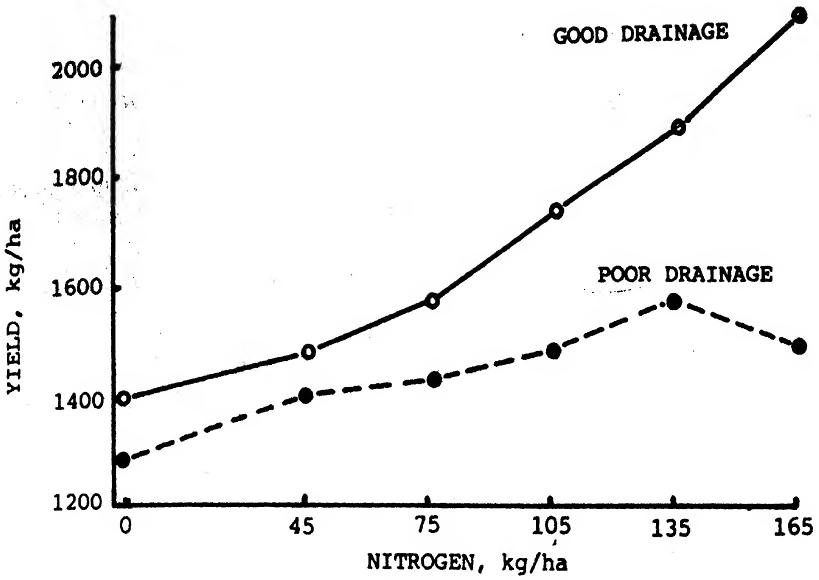

FIG. 4.7. EFFECT OF NITROGEN APPLICATION ON TEA YIELD UNDER GOOD & POOR DRAINAGE STATUS

Yield increased in both the cases with increasing dose of nitrogen, but esponse was much higher in good drainage condition. Response in yield at 20 - 150 kg N/ha under poor drainage condition was same as that of 60 - 0 kg N/ha under good drainage condition. This clearly shows that when the ushes are grown under good drainage condition, they are in a better position to utilise the fertilizer more efficiently and the response in yield is aintained upto the observed maximum level i.e. 150 - 180 kg N/ha, whereas nder poor drainage condition, the yield declined beyond 120 - 150 kg N/ha.

5

DRAINAGE OF FLAT LANDS UNDER TEA PLANTATION

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Introduction

Groundwater drainage is defined as the removal of water from the root zone by lowering the groundwater table. It can be accomplished by correctly spaced deep open drains of various sizes and shapes, underground pipe drains or by a combination of both.

Earlier, shallow open drains were provided in tea areas to collect the surface runoff but the current practice is to have deeper drains to drain the subsoil water as well. Therefore, as far as possible, the drains are being deepened further depending upon the availability of outlet. Since, the design of suitable drainage system requires information about soil, topography, source of excess water and amount of excess water, the experiments have been taken up to evaluate these variables. Without the necessary investigation of above mentioned parameters and detailed survey, it is not possible to recommend the size, shape, depth and spacing of drains in a particular area. The preliminary survey of the proposed drainage project in an estate is, therefore, an important initial investigation to avoid further complications that may come up at the later stages of planning a drainage system.

Preliminary survey

The survey should include the following aspects:

i) Land topography - natural depressions and waterways etc.

ii) Soil properties - texture, structure, permeability, porosity, bulk density etc.

iii) Outlet availability - distance of natural outlet from drainage area, elevation of outlet and elevation of most low lying areas to be drained.

iv) Rainfall, runoff, seepage and deep percolation data.

v) The high flood level of the river in drainage basin.

vi) The size and location of bridges, culverts, rivers, P.W.D. roads and railway lines.

vii) The size of the area to be drained.

The topographic survey gives a clue to the type of drainage system needed and location of drains in a given area. The soil properties affect the shape (cross-section), side slope, and bed grades of the drain.

The information regarding availability of outlet helps in deciding the depth and the maximum length of the drain.

The drainage system is then designed and drain spacings are calculated. The design requirement and procedure followed are as follows.

Design of open drains

A properly designed drainage system should provide the following conditions:

i) velocity of flow such that neither serious scouring nor sedimentation will result,

ii) sufficient capacity to carry the design flow,

iii) hydraulic grade line low enough to drain the land,

iv) side slopes will not cave-in or slide into the drain.

The design of an open drainage system includes mainly the shape, size, depth, bed grade, side slope, alignment, junctions and spacing of drains which are briefly discussed below:

1. Drain shape

The shape of the drain is determined from the texture and stability of the soil. Open drains are mostly designed with trapezoidal cross section (Fig. 5.1)

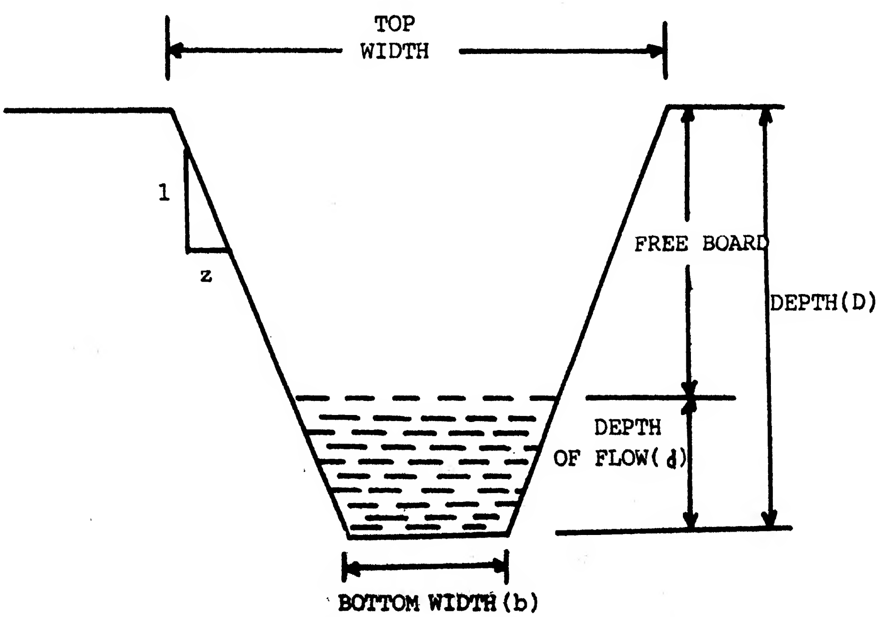


FIG. 5.1 SHAPE OF A MAIN DRAIN

2. Drain depth

The depth of the drain mainly depends on the availability of outlet. The depth of laterals (secondary drains) should be sufficient to adequately drain the subsoil water. For this purpose, the laterals require a minimum depth of 105 cm. The depth of sub-main and main drains should not be less than 120 cm and 150 cm respectively.

3. Side slope

The practice in North East India is to have almost vertical sides of laterals (secondary drains). Wherever it is known that vertical sides of the drains are not stable it is necessary to dig the drains with sufficient side slope to ensure that drain sides do not collapse. The side slope of the drain is determined principally by soil texture and stability. Most critical condition for caving occurs after a rapid drop in the flow level that leaves the drain bank saturated. Suggested standard side slopes for different types of soil are presented in Table 5.1

Table 5.1 Side slope for open drains in tea soils

Soil type	Designed slope horizontal : vertical (as per angle of repose)	Practical slope horizontal : vertical
Loamy sand	2 : 1	0.5 : 1
Sandy loam	1.5 : 1	0.25 : 1
Silt loam, loam and clay-loam	1 : 1	vertical

4. Bottom width : After the drain depth and side slopes are selected, the bottom width for the most efficient cross section can be determined by using standard formula:

$$b = 2\ d\ \tan \frac{\theta}{2}$$

where : b = bottom width of the drain, cm

d = designed depth of flow in the drain, cm

θ = side slope angle in degrees.

5. Drain bed grade and permissible velocity

The bed grade of the drain is determined largely by the natural slope of the land, drain depth and outlet elevation. The steeper the grade, higher will be the velocity and discharge for the same cross-sectional area of the drain. But excessive grade produces very high velocities which cause erosion. The grade usually ranges from 0.05 to **0.5% i.e. 5 to 50 cm drop in 100 m**

um. Silting may take place in the channel if the grade is less than 0.05%. For determining the grade, the velocities should be checked and the maximum grade designed so that the velocities do not exceed the maximum permissible velocities presented in Table 5.2. Manning's formula is commonly used to calculate the safe velocity for a given cross-section of a drain.

Manning's formula :

$$Q = a\ v$$

and $$V = K_m\ R^{0.667}\ s^{0.52}$$

where : Q = designed flow, cum/sec,

a = cross-sectional area of the drain, sq.m.,

v = velocity of flow in the drain, m/sec.,

K_m = Manning's coefficient ≐ 42 under normal conditions,

R = hydraulic radius = $\frac{a}{p}$, m

s = hydraulic slope, m/s.

Table 5.2 Maximum permissible velocities for various soil textures and drains clear of weeds

Type of soil	Maximum permissible velocity, m/sec
Loamy sand	0.45
Sandy loam, silt loam	0.60
Loam	0.65
Clay loam	0.70

Drain spacing

The drain spacing depends mainly on the following:

i) depth of drain,

ii) effective rate of rainfall in the drainage area or drainage coefficient,

iii) equivalent depth to impermeable layer below the drain bed,

iv) soil hydraulic conductivity (permeability) and porosity,

v) maximum permissible height of water table above drain bed.

Because of many variables involved and soil differences in various parts of North East India, it is not possible to develop a general method which will be satisfactory for all situations. The drain spacing is, therefore, calculated for each area independently based on the values of the above parameters.

Procedure for calculating drain spacing in flat lands is different from that of sloping lands. There are more than 40 steady state, 10 unsteady state, and 10 empirical drain spacing formulas available in drainage literature. However, Hooghoudt's steady state equation is commonly used in drainage system design in plains because of its simplicity.

Hooghoudt's Formula:

$$S^2 = \frac{4\,K\,H_m}{q}\,(\,2\,D_e + H_m)$$

where:
S = drain spacing, m
K = soil hydraulic conductivity, m/day
H_m = height of water table at midpoint between the two drains above the bed lèvel of the drain, m
q = drainage coefficient, m/day
D_e = equivalent depth to impervious layer below the drain bed level, m.

Grice (1971) suggested a procedure for calculating drain spacing in sloping lands. This procedure is based on a formula used for spacing terraces for soil erosion control in areas where soil erosion is the main problem and generally rainfall is not as high as experienced in North East India. Grice further stated that 'sticking strictly to these formulas will certainly control soil erosion, but it will be found that if used in North East Indian conditions without adjustments for slopes below 3% the distance apart of the drains will be so great that they will not meet the other essential requirements of efficient water disposal'.

It was therefore, suggested that the horizontal distance between drains for slopes below 3% be based on calculation for a 3% slope in the interim period until more information about runoff details under varying conditions of slope, soil and rainfall is available. Planning open drainage system based on topography has been very popular with the tea industry. The most serious problem faced is to dig the drains on the contours in existing mature tea as this requires uprooting of a large number of bushes to have the properly aligned drains. Drains dug to pass through the space between the two tea bushes without uprooting the bushes falling in the way, will be zig-zag and will have sharp turns with varying sizes, which is highly undesirable. This problem may, however, not be so serious in uprooted or extension areas where tea can also be planted along the contours.

7. Drain size

The size of a drain depends mainly upon side slope, bed grade, maximum permissible velocity, drain depth, shape of its cross-section, drainage coefficient and total quantity of water to be carried out by the drain.

The drainage coefficient, which is the depth of water to be removed from a drainage area in 24 hours time, involves a complex of hydrologic factors such as rainfall, surface runoff, seepage into and out of the area, percolation lo~ses, soil moisture storage, consumptive use of tea and evaporation

osses etc. It is, therefore, quite difficult to evaluate the drainage coefficient accurately. Nevertheless, for practical purposes important factors like effective rainfall and consumptive use of tea can be utilised to arrive at a reasonable figure of drainage coefficient which can be considered in the design of drain for the time being.

The drain cross sectional area, bottom width and top width can then be calculated from standard equations. An idea of the requirement of drain size for sandy-loam type of soils can be obtained from Table 5.3. However, it may be emphasised that sloping the side walls of laterals is not a recommendation in all the situations but the table simply gives the idea of minimum specifications of a drain which may be useful in unstable and loose soils.

The drains are usually not designed for maximum permissible velocity but are designed for self cleaning and non-erosive velocity. A minimum velocity of 45 cm/sec is required to keep the drains clean. The same value of velocity is used in the calculations for drain dimensions presented in Table 5.3.

Table 5.3 Design specifications of drains in medium textured-soil (sandy loam type)

Drain	Drain depth, cm	Top width, cm	Bottom width, cm	Mini. desirable Bed grade %	Depth of flow in the drain, cm
Lateral drain	105	45	15-20	0.25	10
Sub main drain	120	75-100	30-50	0.15	15
Main drain	150	100-150	50-100	0.10	30

It may be seen that the hydraulically designed lateral drains will require a large area of land. The common practice in tea industry, therefore, is to have the drains dug in between the two rows of tea. These drains may not meet the design requirement particularly when they are deeper than 0 cm and will demand for regular maintenance every year to function effectively.

Alignment of main drain

Proper alignment includes the design of straight drains and, wherever necessary, gradual curves to prevent excessive bank erosion. The radius of curvature depends on the velocity of flow and stability of the side slopes.

Drain junction

The junctions of the drain with another should be such that serious bank erosion, scour holes, or sedimentation will not occur. The laterals should be designed to enter the larger drain at an angle less than or equal to 90° (maxi.) with the direction of water flow in the larger drain.

There must not be any overfall at the drain juctions. The laterals and sub-mains should join at the same bed elevation. If the laterals are shallower

than the sub-mains, the overfall at the junctions may be eliminated by increasing the grade of the lateral in the last 10-20 m or by increasing the slope on the entire lateral. A steep grade at the junction is not desirable but may be better than having an overfall. Since maximum velocities occur at the higher stages, the increased grade near the outlet may not be serious because the water in the sub-main drain will back-up into the laterals.

10. Drain location

After the drainage system has been designed, one can proceed with the field layout. The general location and alignment of the drains has normally been determined by the preliminary survey. A few general rules for locating the drains are given below:

i) For main drains and sub-main drains, follow the general direction of natural waterways,

ii) Large size drains should be straight as far as possible or with gradual curves, if required,

iii) Locate a drain along the estate boundary, if practicable,

iv) Make use of existing drainage system as much as possible,

v) Use the available grade in flat lands to best advantage,

vi) Avoid locating drains in a place where it will require expensive structures and maintenance.

Types of drainage system (i)

In general, the types of drainage system required in tea soils are (Fig. 5.2):

(i) Random
(ii) Herringbone
iii) Gridiron
(iv) Interceptor

(i) Random

This system is adopted to drain out small, isolated, wet low areas. The drains are dug through the natural depressions.

(ii) Herringbone

It is adopted to areas where the land slopes to middle from both directions. The main drain is dug in the low land normal to the land slope. In this case, the laterals join the main drain from both sides.

(iii) Gridiron

In this case, the laterals enter the main only from one side. Where the width of waterway is more, a main is constructed along both sides of the waterways.

(iv) Interceptor

It is dug near the upper edge of a wet area. This condition normally exists along waterways. To drain such areas, the interceptor drain shall be installed on both sides of the waterways.

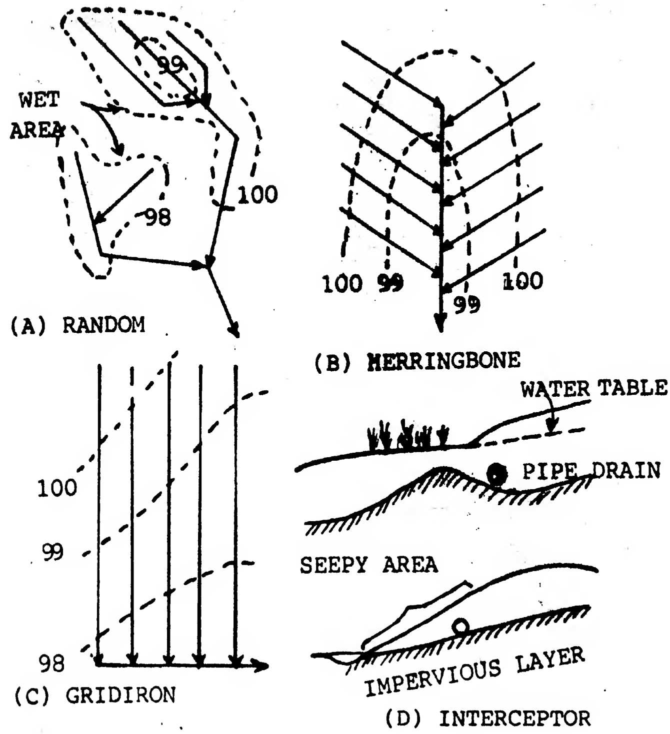


FIG. 5.2 TYPES OF DRAINAGE SYSTEM

In flat lands, the lateral drains can be dug at the required grade in the direction across the general slope of land or in the direction of general slope according to need and convenience in working and planting tea. The drainage system having long sub-main drains with short laterals (secondaries) is called the herringbone system. The drainage system consisting of long parallel laterals (secondaries) connected to a short sub-main is called gridiron system. The gridiron pattern is more economical than the herringbone system because the number of juctions and the double drained area are reduced.

11. Drain construction

Digging of the drain should start at the outlet end and proceed upgrade. The main drains should be dug first, followed by sub-main drains, and then the laterals. The digging in unstable soils should be carried out in stages otherwise there would be danger of collapsing of the side walls due to excessive seepage pressures on the walls.

12. Spoil banks

The spoil bank (excavated soil) of all the drains should be spread evenly over the area. If for some rasons the excavated soil cannot be spread, it should be placed on one or both the sides of the drain at least 3 m away of the bank so that its weight does not cause instability to the drain bank.

13. Period of drain construction

The period for drain construction is mainly decided on the basis of the

degree of soil wetness. Digging should be avoided in wet soil conditions as this damages the soil structure. The best period for digging drains in this region would be the cold weather i.e., November to March/April.

14. Length of drain

If the land slope is such that the drains can run parallel to the soil surface, there is no limit to drain length except that imposed by the topography. On level lands, a drain on a slope of 0.15 percent, will drop 30 cm in 200 metres, and this distance becomes about the maximum permissible length of the drains. Similarly, a drain laid out on a slope of 0.05 percent will drop 30 cm in 600 metres, and this distance becomes about the maximum permissible length of the drains in this case.

Advantages of open drains

i) initial cost is low;

ii) easy to construct by manual labour,

iii) they are able to carry large quantities of water,

iv) they can be commonly used as collectors or main drains,

v) they can be used as conveyance channels for surface runoff,

vi) they can be used to control the water table if dug to the required depth.

However there are certain difficulties with open drainage system which are listed below:

Disadvantages of open drains

(i) Land removed

Open drains of required size and slope will occupy a large amount of land, which otherwise could be planted with tea.

(ii) Bridges and crossing

Open drains may require several bridges, culverts and other structures for labourers and vehicles to cross. These expensive structures will additionally present maintenance problems.

(iii) Maintenance

Open drains are more difficult to maintain than the pipe drains. It is observed in many tea estates that a number of open drains are not fully effective for drainage due to inadequate and lack of timely maintenance.

Causes of Drain Failure

It is difficult to keep open drains operating efficiently in unstable and loose soils. Major causes of their failures are:

(a) Sedimentation in the drain channel

Most of the sediment that comes into the drain is due to erosion of the surrounding land and scouring within the drain itself. Soil scouring and siltation in the drain occurs if the bed grade is not adequate and uniform throughout the length of the drain.

(b) Improper location and alignment of drains

It causes serious bank erosion of the drain. In unstable soils even the gradual turns may not be able to eliminate erosion in the drain.

(c) Improper junctions

Improper junctions of one drain with another and overfall at the junctions cause serious bank erosion, scour holes or sedimentation in the drain.

(d) Inadequate size and shape of the drain

The deep drains (depth more than 90 cm) dug in the available space between two tea rows do not usually meet the design requirement of a drain. Such drains will require regular maintenance if they are to do the job they are meant for.

(e) Inadequate culvert and bridge capacity

(f) Improper land use on the watershed

(g) Excessive growth of weed in the drains

(h) Blockage of natural waterways/outlet drains

It is clear that in many situations it would be extremely difficult to keep the open drains operating effectively, particularly in unstable soils, without regular maintenance. In order to control the water table 90 cm below the ground surface, the lateral drains will have to be 105 cm deep (minimum). The deep drains with trapezoidal cross-section will occupy much valuable land. A great deal of unnecessary and expensive maintenance is caused by faulty drain construction in unstable soils. Many cases are seen of collapsed drain sides as a result of not having proper design. It, therefore, becomes important to find out the possibilities of an alternative drainage system for unstable and loose soils where deep open drains with nearly vertical sides fail to work effectively. One alternative, which is being evaluated at Tocklai, is the underground pipe drainage system.

It is realised from literature that in comparison to open drains the pipe drains require less maintenance. The pipe of adequate size laid at a required grade with properly designed envelope material will cause no problem of siltation or deposition of sediments in the drain. However, the areas where springs feed the pipe drains, the roots of shade trees and tea bushes may grow into the pipe and obstruct the flow. In this case, the drain pipes have to be cleared periodically. Most important is the high initial cost of pipe drainage system which must be considered carefully before this is adopted.

EXPERIMENTAL RESULTS

Drainage of lands having rolling topography and fed by seepage flow

This project area covered about 25.52 ha under improved drainage. The tea was about 25 years old. The soil belonged to loamy-sand texture with very bouldery subsoil. The effective rootzone was found to be within 45 cm. The area was poorly shaded. The weed control was fairly satisfactory.

The data on crop yield showed that the yields from project area were following a declining trend since 1981. The yield was only 2522, 2293 and 1825 kg/ha in 1981, 1982 and 1983 respectively. The drainage project was started only in 1984.

One of the most important factors responsible for low yield and for the declining trend of yield, was found to be the rootzone waterlogging. The major source of excess water was subsurface seepage flow. The data on water table showed that the flat top portion of the ridges normally does not suffer from waterlogging (Fig. 5.3). The water table there fluctuated between 90 and 120 cm depth below ground level excepting a few times and that too only for a short duration. On the other hand, the water table on the two sloping sides of the ridges was found to be fluctuating between 20 and 90 cm, depth below ground. The results indicated that under normal circumstances there will be no need to provide deep and intensive drainage system on the top flat portions of the ridges. But the sloping sides will undoubtedly demand for an intensive drainage system. This is contrary to common belief that sloping sides are self drained and do not require drainage.

The data recorded on rainfall, % area under LP and crop yield in kg/ha made tea for the year 1980 to 1985 have been presented in Table 5.4. Though 1983 was the pre-drainage year but 1982 was taken as a base year for crop comparisons since 1982 and 1985 have been the LS year and 1983 was LP year.

Table 5.4. Crop yields as influenced by drainage in lands with rolling topography

Year	Pruning	Rainfall, mm	Yield, kg/ha	% increase in yield over 1982
1985	LS	5019	2612	+13.9
1984	UP	5174	2920	+27.3
1983*	LP	5349	1825	-20.4
1982+	LS	4839	2293	-
1981	LS	5092	2522	-
1980	DS	6485	1740	-

* Pre-drainage year

\+ Base year for comparison of yields

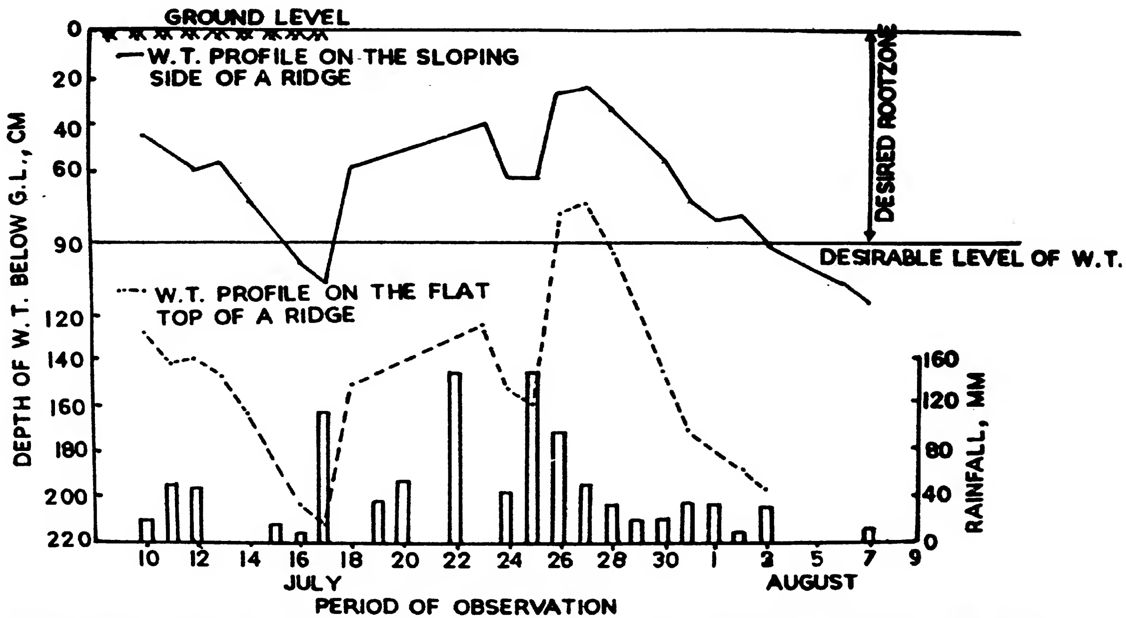


Fig. 5.3. WATER TABLE PROFILE ON TOP FLAT PORTION & SLOPING SIDE OF A RIDGE

The data showed an increase of 13.9 and 27.3% in yield in 1985 and 1984 respectively over that of 1982.

The other management practices and inputs were kept more or less the same as before.

Drainage of sandy loam soils having flat topography and affected by naturally high groundwater table

A drainage project covering about 48 ha of land under tea was started in 1984. The soil of project area belongs to medium texture i.e. sandy loam type. The major source of excess water causing waterlogging has been identified as local rainfall. The area suffers from a naturally high groundwater table throughout the rainy season and is also prone to surface floods due to backflow from the river.

A relief drainage system was designed having 105 cm deep laterals at 30 m spacing in gridiron pattern.

The W.T. data plotted in Fig. 5.4 show that the scientifically designed drainage system could effectively control the groundwater table below the desired 90 cm level throughout the period of observation whereas in conventionally drained area, the water table remained in the rootzone all throughout this period and was found to be as close as 40 cm to the ground surface.

The data on crop yield (made tea, kg/ha), % area under LP, and rainfall are presented in Table 5.5. Though 1983 was the pre-drainage year but 1982 has been taken as the base year for all comparative studies since the area under LP was exactly same i.e. 23.65% in 1982 and 1985. The data show an increase of 30.7 and 31.6% in 1984 and 1985 respectively over the base year (1982) yields. There was a net increase of 8.51 Q/ha in the yield of 1985 over that of 1982 inspite of the fact that the project area was badly affected by surface flood from a close by river in 1985 and also received 480 mm more rainfall than in 1982.

Table 5.5 Effect of improved drainage on yields of tea planted in deep sandy loam soil with flat topography (project area 48 ha).

Year	Rainfall mm	% area under LP	Yield made tea, kg/ha	% increase in yield over 1982	Remarks
1985	4384	23.65	3549	+31.6	The tea in project area suffered from flood in 1985
1984	4824	Nil	3527	+30.7	
1983*	4043	76.35	2170	-19.6	
1982+	3904	23.65	2698	-	
1981	2727	Nil	2659	-	

*Pre-drainage year

+ 1982 taken as the base year for data comparison

Drainage of deep silty loam soils having flat topography and affected by subsurface seepage flow

A drainage project was started in 1983 covering 138 ha of land under old mature teas. The soil of the project area belongs to silty loam texture. The subsoil was denser and compacted. The major source of excess water causing waterlogging was subsurface seepage flow combined with local rainfall.

The water table profiles as observed in experimental and control plots during a typical rainstorm in July 1985 have clearly shown that the improved drainage system could very effectively control the water table below the optimum rootzone depth i.e. 90 cm throughout the rainstorm whereas in conventionally drained area, the water table remained in the rootzone all throughout this period. The water table was found to rise as close as 26 cm to the ground level in conventionally drained area (Fig. 5.5).

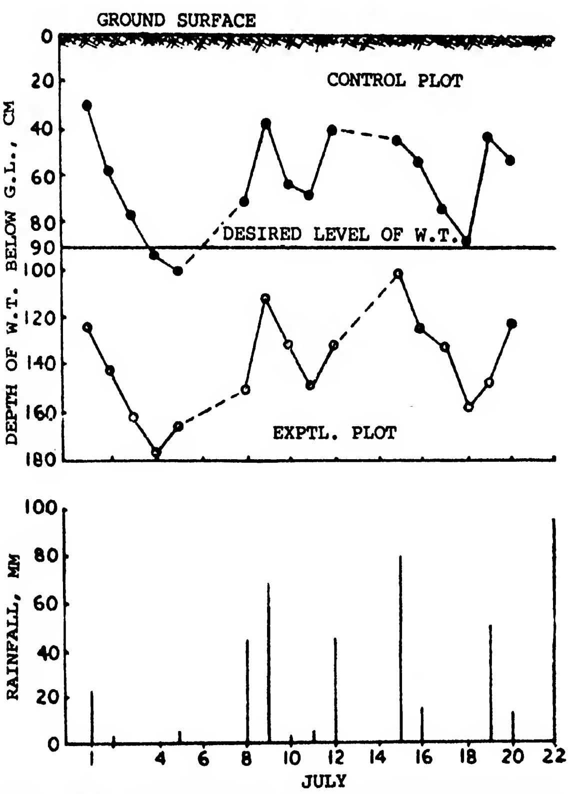


FIG. 5.4. WATERTABLE PROFILES IN EXPERIMENTAL AND CONTROL PLOTS AS OBSERVED FOR A TYPICAL RAINSTORM

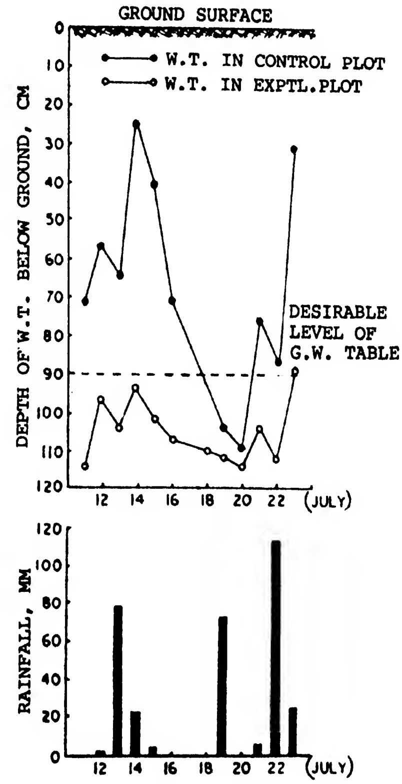


FIG. 5.5. WATER TABLE PROFILE IN EXPERIMENTAL AND CONTROL PLOT FOR A TYPICAL RAINSTORM DURING JULY 1985

The data on crop yields (made tea, kg/ha), % area under LP and rainfall are presented in Table 5.6. The data show that the yields of 1981 and 1982 were more or less the same i.e. 1227 and 1223 kg/ha respectively inspite of 8% less area under LP in 1982. The drainage project was started in 1983. In the first year itself, the increase in yield was recorded to be 200 kg/ha over that of 1982 yields inspite of 16.3% more area brought under LP in 1983. The increase in yield over 1982 has been 16.7, 42.2 and 43% in 1983, 1984 and 1985 rspectively. In 1983 (first year of drainage project) and in 1985 (3rd year of project), the area under LP had been exactly same i.e. 29.7% of the total. The rainfall of 1985 has been 1662 mm less than that of 1983 and 1128 mm less than that of 1984. Even then the yields of 1985 have been 322 kg/ha more than that of 1983. A total increase of 5.20 Q/ha has been recorded in 1985 over the predrainage year, 1982

Table 5.6. Crop yields as affected by improved drainage in flat lands.
Project area - 138 ha

Year	% area under LP	Rainfall, mm	Yield, kg/ha	% increase in crop over 1982	Remarks
1985	29.7	2213	1749	43.0	In 1985 there was a severe infestation of Red slug during first and second flush period.
1984	47.3	3341	1739	42.2	
1983	29.7	3875	1427	16.7	
1982*	13.4	2865	1223	-	
1981	21.4	3156	1227	-	

* Pre-drainage year

It will be worth mentioning here that the tea in project area was severely damaged due to heavy infestation of red slug during first and second flush period in 1985 otherwise the yields could be further higher.

Drainage of flat lands affected by rainfall

A large scale drainage project covering about 555 ha of area was started in 1984. The soil of project area belongs to sandy loam texture. It is quite deep and homogenous in nature. The subsoil is relatively denser, grey in colour and a bit compacted. The major source of excess water causing waterlogging is identified as local rainfall which is very intensive at times. Some portions of the project area, however, also suffer from spring flow.

The project area was provided with a drainage system comprising of 150 cm deep main drains, 120 cm deep submain drains and 105 cm deep laterals in herringbone pattern at a spacing of 30 m ± 3 m.

The crop yield data (made tea, kg/ha), % of area under LP and rainfall (mm) for the period 1981 to 1985 are presented in Table 5.7. The data show that there was declining trend in yield for the pre-drainage period of 1981 to 1983 inspite of much reduced area under LP every following year. The yield of 1981, 1982 and 1983 was 2000, 1993 and 1968 kg/ha respectively. The waterlogging was identified as one of the major constraints responsible for low production.

The yield data recorded from the drainage project area showed an increase of 11.2 and 21.7% in 1984 and 1985 respectively over that of 1983. The increase of 2.20 Q/ha and 4.26 Q/ha in 1984 and 1985 respectively has been inspite of 721 and 104 mm more rainfall received in 1984 and 1985 respectively than in 1982. The garden adopted a much finer plucking standard (8-9 days round) in 1985 as compared to previous years (10-12 days). The other management practices and inputs were maintained more or less the same as before.

Table 5.7. Effect of improved drainage in flat sandy loam soils affected by heavy rainfall. Project area 555 ha

Year	Rainfall, mm	% area under LP	Yield made tea kg/ha	% increase in yield over 1983
1985	4082	29.0	2394	+21.7
1984	4699	27.3	2188	+11.2
1983*	3978	22.0	1968	-
1982	3209	26.3	1993	-
1981	3888	28.2	2040	-

* Pre-drainage year

Ill-effects of ignored drainage system installed in shallow sandy loam soils having flat topography

A drainage project covering about 114 ha area with flat topography having old mature tea was initiated in 1981. The water table data showed a build up of high water table during rainy season which fluctuated between 20 and 45 cm depths below the ground surface. Due to this reason, the rooting system was very shallow and inadequate in volume.

The data on crop yields, % area under LP and rainfall for the period 1981 to 1985 have been presented in Table 5.8. The drains in the experimental area worked quite satisfactorily upto 1983. During this period an increase of 34.4 in 1982 and 36.7 in 1983 was recorded over the base year (1980). An increase of 4.48 Q/ha in 1982 could be possible inspite of the fact that no manuring could be done in the garden that year due to financial difficulties.

Unfortunately, after 1983, the garden could not look after and maintain the drainage system in experimental area. As a result, the drains got silted up and badly infested with weeds. The culverts got choked and the outlets were blocked by busti people for lifting water for irrigation and for fishing. Though other crop management practices were more or less the same as before, the yields of 1984 and 1985 showed a decline. A decrease of 65 kg/ha in 1984 and a further decrease of 86 kg/ha in 1985 as compared to 1983 yields is recorded; the yields of 1985 have been 1.51 Q/ha less than that of 1983. It is believed that the drop in yield has been mainly due to inadequate maintenance of drainage system.

Table 5.8. Ill-effect of an ignored drainage system on crop yields
Project area-114 ha.

Year	Total rainfall mm	% area under LP	Yield, made tea kg/ha	Increase in crop over 1980(Base year)
1985	3516	37.50	1630	25.0
1984	3542	17.82	1716	31.7
1983	4054	30.57	1781	36.7
1982	2596	14.03	1751	34.4
1981*	3452	41.03	1568	20.3
1980+	3392	27.09	1303	-

* Pre-drainage year
\+ Base year

Exercise

Determine the size of main outlet drain for the conditions given below:

Drainage area (A)	= 100 Ha
Drainage coefficient (DC)	= 25 mm per day
Permissible velocity of flow in the drain (v)	= 60 cm/sec
Drain side slope (z)	= 0.25 : 1
Designed depth of flow in the drain (d)	= 50 cm

Solution

Discharge (Q) = DC x A

$$Q = \frac{25}{1000 \times 24 \times 60 \times 60} \times 100 \times 10{,}000$$

$\therefore Q = 0.29$ cum/sec

Now: $Q = V.\ a$

$0.29 = 0.6 \times a$

$\therefore$ Cross-sectional area of drain (a) $= \frac{0.29}{0.60} = 0.48$ sq.m.

For trapezoidal drains : $a = bd + zd^2$

$0.48 = 0.5b + 0.25 \times 0.50^2$

$\therefore$ Bottom width of the drain (b) = 0.835 m

Wetted Perimeter of the drain (P) $= b + 2d\ (z^2 + 1)^{\frac{1}{2}}$

$= 0.835 + 2 \times 0.5\ (0.25^2 + 1)^{\frac{1}{2}}$

$= 1.866\ \text{m}$

Hydraulic radius (R) $= \frac{a}{p}$

$= \frac{0.48}{1.866} = 0.26\ \text{m}$

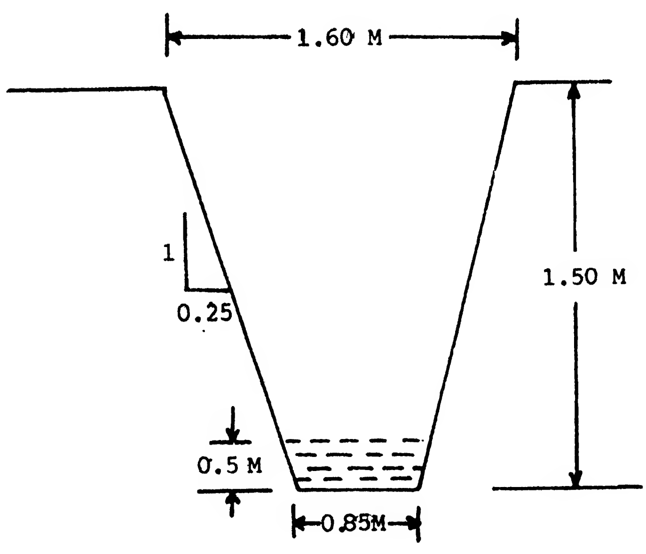
Using Manning's Equation: V $= \frac{1}{n} R^{0.667}\ s^{0.52}$

0.6 $= \frac{1}{0.04} \times (0.26)^{0.667}\ s^{0.52} (n=0.04)$

$s^{0.52} = 0.059$

$s = 3.47 \times 10^{-3}$

$s = 0.35\ \%$



6

DRAINAGE OF STEEP LANDS - DARJEELING HILL SLOPES UNDER TEA

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Introduction

Darjeeling and Cachar belong to an altogether different physical and climatic region than most of the areas under tea plantation in India. These differences dictate the type of soil and water management practices for increased production of high quality tea and sustained high yields. According to basic principles of soil conservation, the lands with slopes steeper than 45% must not be opened for cultivation and should be kept under adequate forest and vegetative cover. It is an exception in the world that Darjeeling hills with slopes steeper than 45% are under tea plantation. The soil and water management, therefore, become extremely important in Darjeeling hills and Cachar teelahs.

Climate

There are 9 valleys in Darjeeling. The intensity and distribution of rainfall varies considerably from valley to valley. It varies from as low as 1500 mm to as high as 4100 mm with an average of about 3000 mm per year. Rain storms of intensity as high as 100 mm in an hour, 350 mm in 9 hours, 950 mm in 48 hours, and 1550 mm in four continuous days have also been recorded at our meteorological observatory in Darjeeling. The data analysis further indicates that about 96% of the total annual rainfall is received during the period April to October (7 months).

Soil

The soil, by and large, belongs to fine to medium texture. The typical Darjeeling soils are chocolate coloured loam and silty loam type. The soils are fairly uniform but shallow in depth. The top soil is about 45 cm deep and the subsoil has stones and big rocks underneath. The infiltration rates are rather low i.e. 6 to 10 mm/hour. The soils are acidic in nature and have high silica content.

Topography

Darjeeling has rather difficult topography of varied nature. The land slopes vary from nearly flat (plateau) to as steep as 275% (70°) or even more. In some areas, the land has highly undulating and rolling topography. Tea is grown on the sides of the valley (slope varying from 20 to 300%) and on peaks as high as 2000 metres above m.s.l.

SOIL EROSION

Factors affecting soil management

The factors such as climate, steep slope, stoniness, unfavourable soil texture and structure greatly influence the soil management practices in tea estates of Darjeeling. Improper watershed management, overgrazing, large scale deforestation at a high rate have made the soil management problem very difficult. The land slide and sinking have also been a serious problem of this region.

Problem of soil erosion

Most of the tea in Darjeeling has been planted on steep hill slopes and spurs of ridges. This poses the soil erosion problem of special nature and magnitude. It has been estimated from the available records that in the last 100 years, more than 300 mm of fertile top soil has been lost through soil erosion by water in Darjeeling which is a very high rate. Now, there are several hill slopes left with only very little top soil.

Soil conservation measures

In most of the areas, tea is planted on narrow base level terraces. The vertical side of the terraces is generally protected against slip and erosion by way of providing stone retention walls. This old technique of soil conservation has proved to be useful in conserving soil only to a very little extent.

Since their design is difficult, construction and maintenance is expensive and laborious and since they occupy about 25 to 50% of the land which otherwise could have been brought under tea plantation, the terracing does not appear to be a practical solution any longer. The tea estates like to break the old terraces to get more land available for planting tea to increase production. This, however, may further enhance the problem of soil erosion, if adequate care is not taken.

It is perhaps worth stressing the need for constructive nature of soil management. The soil conservation policies must be positive and encouraging, not restrictive. There is no point in preserving soil and not using it - the demand of the time is to use the soil as efficiently as possible without waste.

Naturally, close growing crops like grasses will tend to cover and protect the soil and the row crops will tend to give less protection, but these general trends can be completely reversed by management practices followed. The published literature reveals the fact that a well-managed, well-grown row-crop can minimise erosion and build-up the soil, and that a badly managed pasture can run down the productivity where there are serious losses of soil and plant nutrients. In fact, erosion depends not on what crop is grown, but on how it is grown. So we may continue growing tea in Darjeeling but with suitable soil and water management techniques for erosion control. In lands with steep slopes, the main drains naturally run down the main slope and as a result, they suffer from serious erosion problems. They go on enlarging in size with time and soon become big gullies. There is a great need to stop further erosion in the main drains by way of suitable soil conservation structures.

Soil conservation techniques for tea soils

(1) Minimum tillage and soil disturbance.

(2) Development of adequate grass cover in the area before uprooting old teas and during the period of soil rehabilitation.

(3) Planting of tea along the graded contours at close spacings.

(4) Adequate mulching with suitable material in newly planted areas.

(5) Strip chemical weed control across the main slope of the land. Use sub-lethal dose of weedicide which will supress the active growth of the weeds but will not totally kill them.

(6) Planting of deep rooted quick growing suitable grasses in all the vacant patches of land and then to infill the area in phases with suitable tea planting material.

(7) Immediately after the terraces are leveled, the area must be covered with a thick layer of suitable mulching material and infilled with tea plants.

(8) Retaining the pruning litter on the surface as much as possible.

(9) Provision for a net work of well designed runoff drains installed across the main slope for effective collection and removal of surface runoff. They can be 30 cm wide, 45 cm deep and spaced 10 to 15 m apart.

(10) Provision for well designed and rightlv located deep interceptor drains for control of groundwater table below the rootzone. They should be minimum 150 cm deep and installed across the main slope.

(11) Use of suitable soil conditioners.

(12) Establishing permanent vegetation in waterways and other eroded areas.

(13) Construct suitable soil conservation structures to stabilize the gully erosion.

(14) Development of artificial water courses to lead away the surface runoff safely e.g. grass waterways, sod waterways. They will run straight down the steepest slope of the land.

(15) Construction of well designed suitable soil conservation structures at all such locations where soil section is relatively more unstable and susceptable to land slide or cave-in.

In general, one or a combination of several techniques mentioned above will need to be followed for better results. It is expected that adequate soil conservation measures in Darjeeling will result in about 25% increase in crop yield (i.e. about 32,00,000 kg of tea). This will also make about 25 to 50% more plantable land available within the existing tea areas (i.e. about 4900 to 10,000 ha).

Drainage

Factors affecting water management

The influence of high rainfall, steep slopes and the complex nature of the underlying rocks results in drainage problems of a special nature. High rainfall on fine-textured soils results in soils of low permeability which become susceptible to compaction, surface capping and chemical and cultivation pans. These soils often develop structureless layers at some depths. It makes natural drainage of sub-soil excess water very difficult.

On the other hand, due to reduced rate of infiltration, more water flows on the surface as runoff and causes excessive loss of fertile top soil. The soil strata of differing permeabilities give rise to springs along their outcrops, some of which can be merely seasonal whilst others may flow throughout the year. A spring or springline often adversely affects a considerable area under tea in Darjeeling.

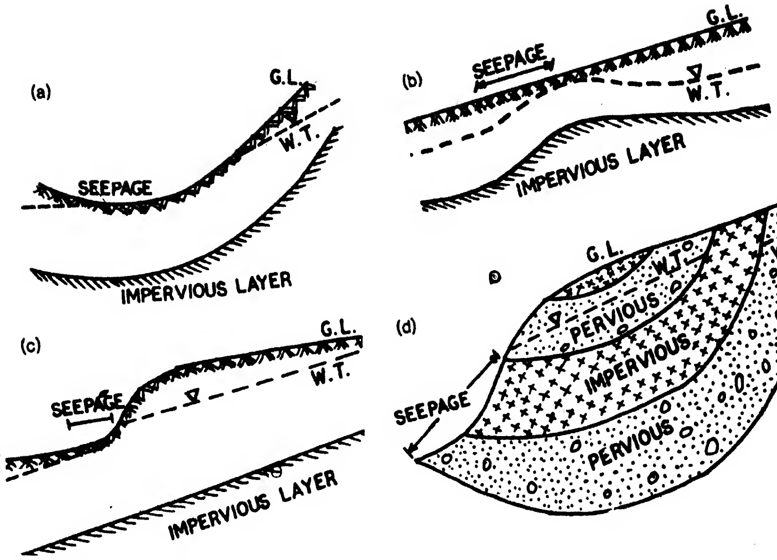
Need for drainage

The seepage flow at shallow depths causes serious water-logging in the rootzone that decays tea roots and restricts the uptake of essential nutrients required for optimum growth of tea. The seepage flow under hydrostatic pressure causes land slide and land sinking problem at places. The provision of well designed interception drainage system will undoubtedly reduce these problems. Large scale investigation work on groundwater table taken up in Darjeeling hills during the period 1982 to 1984 has clearly shown the presence of water table very close to the ground surface irrespective of land slope and altitude. It has been observed that the water table fluctuates between 20 to 75 cm depth below ground level throughout the year. The rainfall received locally had very little or no effect at all on water table. This confirms that the local rainfall is not the major source of excess water causing high water table rather it is subsurface seepage flow from adjacent high lands. The degree of fluctuation of water table mainly depended on quantum and rate of seepage flow and the soil properties. It is the non--steady state condition of groundwater table which is adding to the problem of land slide, soil erosion and land sinking at places.

Situations for interceptor (Fig. 6.1)

It has been observed that on the sloping lands, groundwater usually flows through a pervious upper layer underlying an impervious base. This groundwater flow, often called interflow, causes waterlogging at sites:

(a) where the slope of the land changes from steep to flat,
(b) where impervious layer exists at shallow depths,
(c) where groundwater may rise to the surface at the foot of a slope, and
(d) at the contact of pervious top layer and poorly pervious sub-soil layers outcropping alongside the slope.



(a) SEEPAGE WHERE SLOPE CHANGES FROM STEEP TO FLAT
(b) SEEPAGE WHERE IMPERVIOUS LAYER EXISTS AT SHALLOW DEPTH
(c) SEEPAGE AT THE FOOT OF A SLOPE
(d) SEEPAGE WHERE PERVIOUS TOP LAYER & IMPERVIOUS SUBSOIL LAYERS OUTCROP ALONG SIDE THE SLOPE

FIG. 6.1. SITUATIONS FOR INTERCEPTOR DRAINS

Field investigation

(1) Delimitation of the waterlogged area by field inspection.
(2) Determination of the nature (phreatic, artesian) and direction of groundwater flow.
(3) Determination of the lateral extension, thickness, slope and hydraulic conductivity of the water bearing strata.
(4) Water table and hydraulic head measurements.
(5) Depth to impervious layer.

Interceptor drainage system

1. Type of the system

Interceptor drain is planned as a single random drain in some sections of land and also as a series of parallel drains.

2. Drain depth

The objective remains that the interceptor drain should be placed as deep as it is practical to install in a given situation. They are made at least 150 cm deep. It is preferred that they are dug to the impervious layer so as to intercept the maximum amount of seepage flow.

3. Drain type

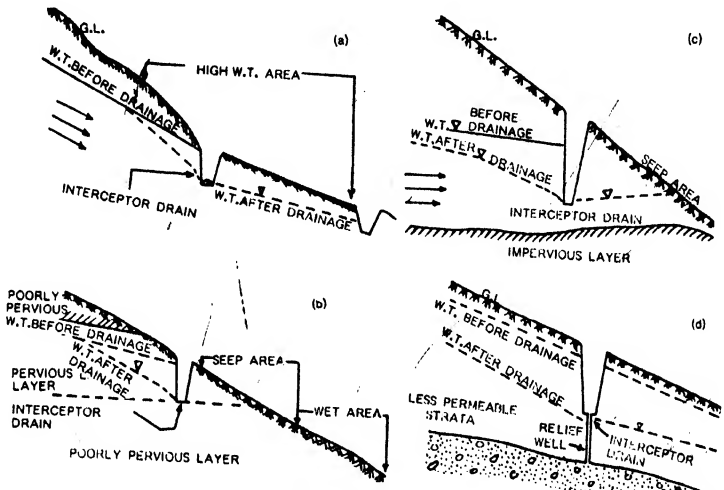
In Darjeeling lands with steep slopes, open drain is considered to be more effective than a pipe drain due to a bridging–over effect in pipe drains.

4. Drain spacing

The interceptor drains are effective for a considerable distance downslope from the drain but the upslope effect is very small and is ignored. In many instances, it is found that a single interceptor has proved to be adequate for a large area. Since it is very difficult to estimate the spacing of interceptor drains, to avoid uncertainities, it is considered feasible to install the system progressively. This is accomplished by digging the first drain to protect the higher portion of the wet area and then other drains are dug after evaluating the effect of the first one.

5. Location of drain (Fig. 6.2)

The location of interceptor drains considered as most appropriate in four situations quite commonly observed in Darjeeling are as follows:



(a) ABRUPT CHANGE IN TOPOGRAPHY
(b) A PERVIOUS LAYER STANDWICHED BETWEEN POORLY PERVIOUS LAYERS
(c) IMPERVIOUS LAYER CLOSE TO GROUND
(d) PERMEABLE STRATA UNDER HYDROSTATIC PRESSURE

FIG. 6.2. LOCATION OF INTERCEPTOR DRAINS

(a) Abrupt change in topography

Abrupt change in slope from steep to flat causes a rise in water table at the base of the slope or a terrace. The corrective measure in this case is to lower the water table by an interceptor drain installed at the base of the hill land or at the base of a higher terrace.

(b) More permeable soil layer sandwiched between poorly pervious layers

In some situations, a permeable layer outcrops and causes a seep affecting a considerable area below. This occurs when soil is highly stratified. The permeable layer carries a considerable groundwater with a hydraulic grade line that intercepts the ground surface at some point in the outcrop area causing a natural seep. Interceptor drain is located at the base of the permeable material to collect the flow from the aquifer.

(c) Impervious layer close to ground

At points, the impervious layer rises close to the ground surface under natural conditions. It causes the hydraulic grade line or water table to rise close to the ground surface. An interceptor drain is located just upslope from the barrier.

(d) Permeable strata under hydrostatic pressure

A high water table is also caused by seepage under hydrostatic pressure in a pervious strata located below a less pervious strata. The presence of hydrostatic pressure is detected by piezometric studies in the seepy area. In case, the upper less pervious strata is so thick that digging of a drain to the required depth is not found feasible, the installation of drain with relief wells is considered useful provided that the effective head is more than 150 cm.

6. Drawdown

Where all the flow originates from foreign source upslope.

Boundary conditions (Fig. 6.3)

Soil is homogeneous, slope is uniform, D-F assumption is valid, the impervious layer exists at certain depth below the drain, the impervious layer and the initial water table have a slope 's' with the horizontal base line.

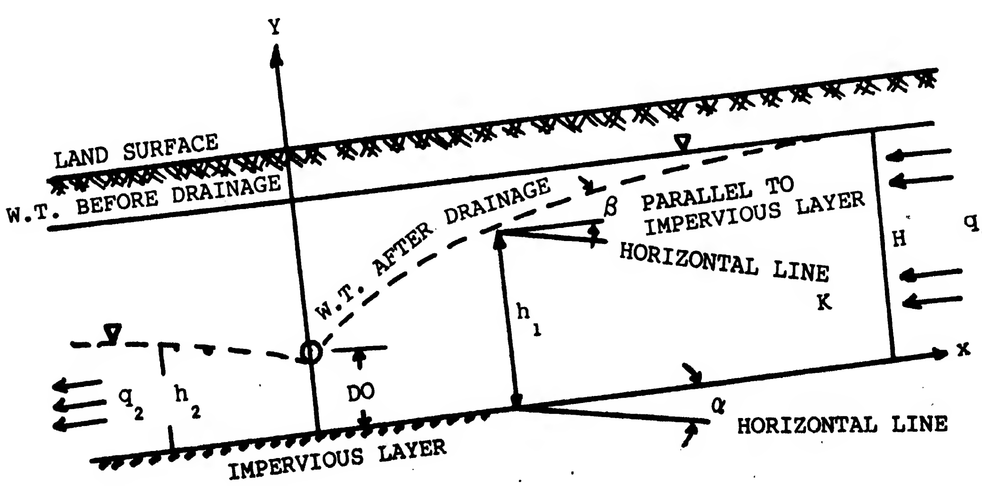


FIG. 6.3 DRAINAGE OF SLOPING LAND WITH ALL THE FLOW ORIGINATING FROM FOREIGN SOURCE UPSLOPE

(a) Drawdown upslope

Glovar's formula in simplified form is found useful to calculate drawdown upslope.

$$X = \frac{4}{3} \frac{H}{S}$$

in which,

X= the distance in metres upslope where the drawdown curve approaches significant tangency with the original water table level,

H= the thickness of horizontal flow of soil water being intercepted,

s = the slope (m/m) of original water table surface.

(b) Drawdown downslope

It, more or less, equals the height of water in the drain provided the radial resistance is negligible.

(c) Drain discharge

To calculate the discharge of the interceptor drain, the following equation is used:

$$Q = \frac{H - h}{H} q_1$$

in which,

Q= discharge of an interceptor drain per unit width (m^2/day),

H= thickness of horizontal flow of water upslope being intercepted (m),

h= water table height above impervious layer downside of the drain (m),

q_1= flow rate per unit width from upslope (m^2/day).

7. Water table control

In areas, where water table was recorded to be fluctuating between 30 and 45 cm depth below ground level throughout the year before drainage, a systematically designed interceptor drainage system was installed to control the water table below the root-zone of tea. The design details of the system are as follows:

Drain type	:	Open drain
Shape	:	Half trapezium
Av. depth	:	150 cm
Top width	:	120 to 150 cm
Bottom width	:	30 to 45 cm
Av. bed gradient	:	2%
Location	:	Interceptor drain was placed at about the upper boundary of the wet area to collect lateral flow coming from known source upslope, thus preventing it from reaching the lower area.
Drain spacing	:	60 to 100 m depending upon specific conditions of an area.

The water table data (Fig.6.4) collected from drainage project sites during 1983 and 1984 have been very encouraging. The data show that the interceptor drainage system has successfully controlled the water table below 90 cm line (rootzone depth of tea) from the ground surface. The water table was observed to be fluctuating between 90 and 150 cm depth below ground level in the experimental area, Fig. 6.4. Since the drainage system was installed, no land slide has been observed in the area. Tea bushes have shown remarkable improvement in their health and vigour. The effect of this geomorphic change in the productivity of tea is being assessed.

The results from several preliminary experiments being conducted in Darjeeling hill slopes indicated that the productivity of mature tea can be increased by a minimal of 15% provided other tea management practices are maintained at their optima apart from reduced problem of land slide, sinking and soil erosion. The experiments on drainage are in progress in several different valleys of Darjeeling hills.

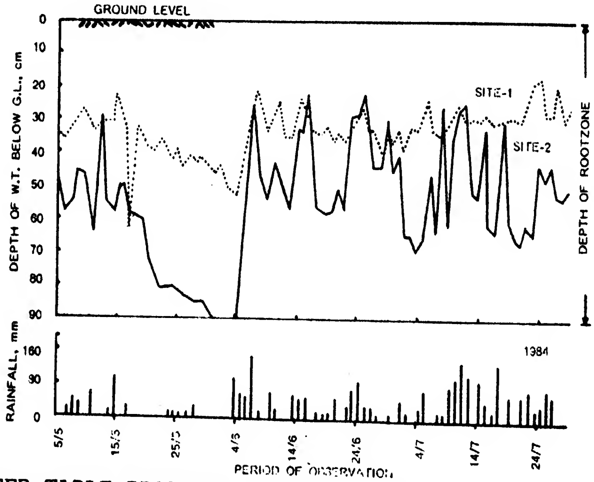


FIG. 6.4(A) WATER TABLE PROFILES IN DARJEELING HILLS UNDER TEA PLANTATION ALTITUDE : 1050 m (a.m.s.l.)

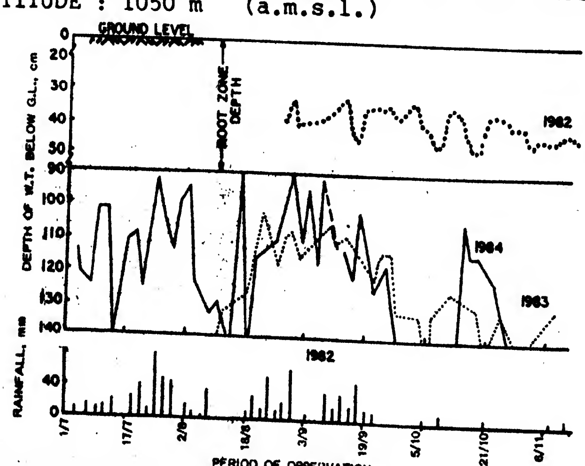


FIG. 6.4 (B) WATER TABLE PROFILE BEFORE & AFTER INTERCEPTION DRAINAGE ALTITUDE OF PROJECT SITE : 1680 m (a.m.s.l.)

Exercise

A homogeneous, uniformly sloping, 500 m wide plain has a slope of 10% The hydraulic conductivity of its 5m thick water bearing layer is 2.0 m/day. The plain is waterlogged because of a lateral flow of foreign groundwater from adjacent upslope land. The initial depth of water table before drainage is 0.25 m. Open interceptor drain is to be installed to control the water table at 0.90 m below ground level:

(1) Find out the discharge of interceptor drain.
(2) Find out the depth of water level in the drain below ground level.
(3) Find out the depth of interceptor drain (Depth of flow = 2.5mm).
(4) Determine the X-section of the drain and bed grade for n=0.018, and maximum permissible velocity of flow 35 cm/sec.

Solution

Given:

$K = 2.0$ m/day, $H = 5.0 - 0.25 = 4.75$ m, $\tan\alpha = 0.1$,
$h_2 = 5.0 - 0.90 = 4.10$ m

$q_1 = K.H. \tan\alpha$
$= 2.0 \times 4.75 \times 0.1$
$= 0.95 \text{ m}^2/\text{day}$

$q_2 = K.h_2. \tan\alpha \quad = 2.0 \times 4.10 \times 0.1 \quad = 0.820 \text{ m}^2/\text{day}$

1. Discharge of interceptor drain

$Q = q_1 - q_2 = 0.950 - 0.820 = 0.13 \text{ m}^2/\text{day}$

Length of drain = 500 m (width of plain)

$Q_T = 0.13 \times 500 = 65$ cu.m/day $= 0.75$ l/sec

2. Drawdown of the W.T. at the drain = $H - h_2$

$$H - h_2 = \frac{H.Q}{q_1} = \frac{4.75 \times 0.13}{0.95} = 0.65 \text{ m}$$

$\therefore$ The water level in the open interceptor drain
= 0.65 + 0.25 = 0.90 m below G.L.

3. Total depth of interceptor drain
= 0.90 + 0.025 (depth of flow)
= 0.925 m

say = 95 cm

4. X-sectional area of interceptor drain -

Assume, shape : trapezoidal & side slope : 0.25 : 1 $\therefore z = 0.25$

Given

Given n = 0.018, V = 0.35 m/sec, d = 0.025 m

$Q_T = a\,V$

$$\therefore \quad a = \frac{Q_T}{V} = \frac{65}{24 \times 60 \times 60 \times 0.35} = 0.00215 \text{ m}^2$$

$$a = bd + zd^2$$

$$0.00215 = b \times 0.025 + (0.025)^2$$

$$\therefore \quad b = 8.6 \text{ cm say } 9 \text{ cm}$$

$$V = Km\ R^{2/3}\ s^{1/2} \quad \left(Km = \frac{1}{n} = \frac{1}{0.018} = 55\right)$$

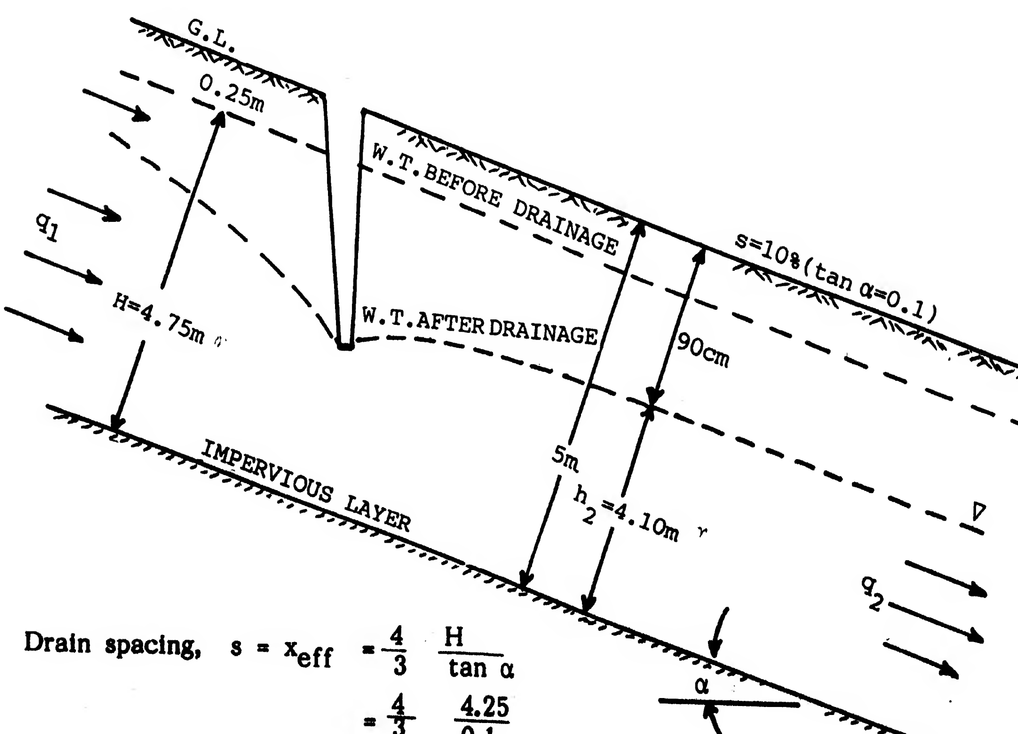
$$\& \quad R = \frac{a}{p} = \frac{0.00215}{0.14} = 0.015)$$

$$0.35 = 55 \times 0.015^{2/3}\ s^{1/2}$$

$$\therefore \quad s = 1\%$$

Size of interceptor drain

Top width	=	56.5 cm
Bottom width	=	9.0 cm
Depth	=	95 cm
Side slope	=	0.25 : 1
Bed grade	=	1%
Depth of flow	=	2.5 cm



$$\text{Drain spacing,} \quad s = x_{eff} = \frac{4}{3}\ \frac{H}{\tan\alpha}$$

$$= \frac{4}{3}\ \frac{4.25}{0.1}$$

$$= 63.33 \text{ m say } 65 \text{ m}$$

7

INSTALLATION AND USE OF SOME IMON DEVICES IN DRAINAGE SYSTEM PLANNING AND MONITORING

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Introduction

There are some common devices like observation wells, piezometers, water level recorders, tensiometers, v - notch, raingauge etc. which are very much useful in drainage investigation, planning and monitoring. The correct way of installation and proper use of these instruments is essential to get correct information on various input data for drain design. The methods of installation and use of some important instruments in water management research and development projects are discussed here.

1. Observation wells (Fig. 7.1)

1.1 Introduction

The water table survey is an important part of any drainage investigation. Observation wells are installed to determine the position of water table at different points in the problem area. Observation wells are also used to determine the extent and degree of severity of the problem. Poor crop production and marshy areas are usually visible evidences of waterlogging. Yet, it is the observation well which gives positive data on the position and fluctuation of the water table. Observation wells usually reflect the free water surface at equilibrium with atmospheric pressure.

1.2 Installation

For observation well, a hole is made with a post-hole auger. The depth of the hole should be such that fluctuation can be measured at least during April to October. This depth is usually 2 to 2.50 m from the ground surface. After digging the hole, about 15 cm of the hole is filled-up with pea gravel. Then the PVC tube with the filter at one end is inserted into the hole. The pea gravel is added to fill up the space around the tube to a depth of about 50 cm from the ground surface. Then the remaining depth is filled up with dry soil. The observation well is protected with a cement concrete structure around it.

1.3 Observation recording

The water table reading is taken daily with the help of a plopper or water level recorder. The data are corrected to read water table depth with respect to ground elevation at that point. The data are then used to plot water table contour maps, isobaths and to study the fluctuation of water table with respect to rainfall.

1.4 Site for installation

The number of observation wells to be installed varies with the size and the topography of the area. For a small watershed the observation well should preferably be installed at a grid spacing of 20 m.

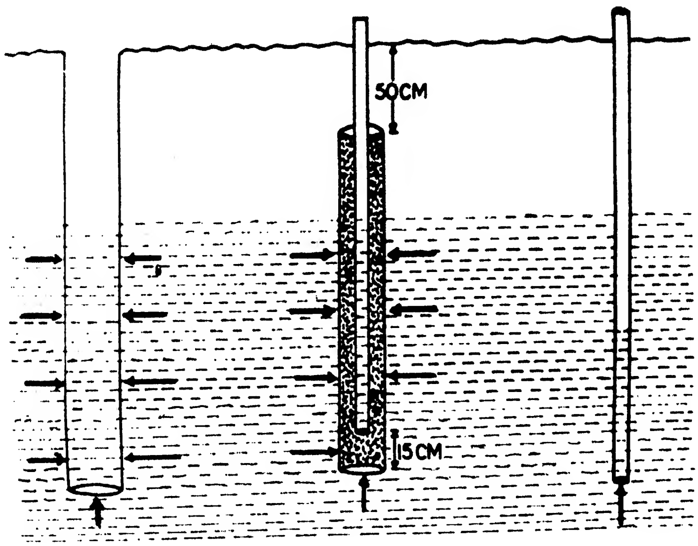


FIG.7.1 AUGERHOLE, OBSERVATION WELL AND PIEZOMETER

2. Piezometers (Fig. 7.1)

2.1 Introduction

One of the most useful tools to employ in drainage investigation of any type is the piezometer. It is a small diameter pipe driven or jetted into the soil so that all entrance of water into the pipe is from the bottom. The observation well reflects the water table, whereas, the piezometer is designed and installed to indicate the hydraulic head or soil water pressure at the bottom end of the piezometer. Underground water moves from a point of high hydraulic head to one of the low hydraulic head. Therefore, by installing piezometers at various depths and locations, the measurement of hydraulic head can indicate the direction of movement of water.

With sets of piezometers terminated at various depths and spacings, the hydraulic head variations of the entire profile may be depicted and seepage movement can be determined. When a piezometer is installed in the centre of a drain, the water level inside the piezometer pipe may or may not be at the same elevation as the water level in the drain. If the water level is higher in the piezometer than in the drain, the indications are that there is upward seepage from the lower soil layer into the drains. If the waterlevel in the piezometer is lower than that in the drain, there is downward seepage from the upper layer and if they are at the same elevation there is no vertical or downward movement.

2.2 Installation

A small diameter (about 2 cm), PVC, rigid pipe, open at both the ends, should be driven or jetted into the soil so that it is tightly fitted with the soil outside. There should not be any leakage between the pipe and the soil. This can be done with a screw type auger whose external diameter is equal to the internal diameter of the pipe. By putting the auger inside the pipe and removing the soil, the pipe can be pushed into the soil.

2.3 Taking reading

The measurements are often taken with an electronic recorder or with a plopper.

3. Water level recorders (Fig. 7.2)

Water level recorder is an instrument for permanently recording the varying levels of water surface. Among other uses, flow data may be obtained by use with weirs and parshall flumes or other water measuring structures.

The rise and fall of the float with changing water levels turns a drum proportionally, as clock controlled pen moves across the chart at constant speed. Resulting graph shows water levels against record of time.

The period of recording may vary from 4 hours to 32 days depending upon chart, gearing and type of clock drive.

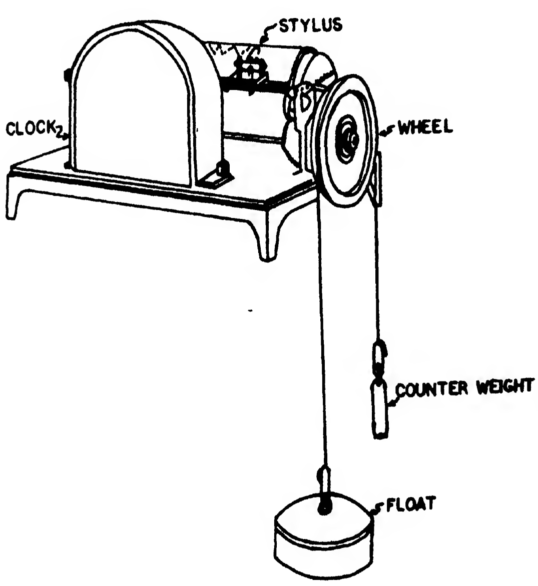


FIG. 7.2 WATER LEVEL RECORDER

4. *Tensiometers (Fig. 7.3)*

4.1 Introduction

The tensiometer consists of a porous cup, generally of ceramic material, connected through a tube to a manometer, which is generally a vacuum gauge, with all parts filled with water. When the cup is placed in the soil where the suction measurement is to be made, the water inside the cup comes in hydraulic contact and tends to equilibrate with soil water. When initially placed in the soil, the water in the tensiometer is generally at atmospheric pressure. Soil water being at sub-atmospheric pressure exercises a suction which draws out a certain amount of water from the tensiometer causing a drop in its hydraulic pressure. This pressure is indicated in the vacuum gauge.

As soil moisture is depleted by drainage or evapotranspiration or it is replenished by rainfall or irrigation, the corresponding readings are indicated by the tensiometer pressure gauge.

Suction measurement by tensiometer is limited to a maximum value of 1 atmosphere. This is because a suction equivalent to 0.85 atmosphere may cause air entry into the cup, which would equalise the internal pressure to the atmospheric pressure.

The general practice is to place tensiometer at a depth of 90 cm representing the root zone of tea plant and to irrigate when the tensiometer indicates that the suction has reached some prescribed value i.e. 0.50 to 0.60.

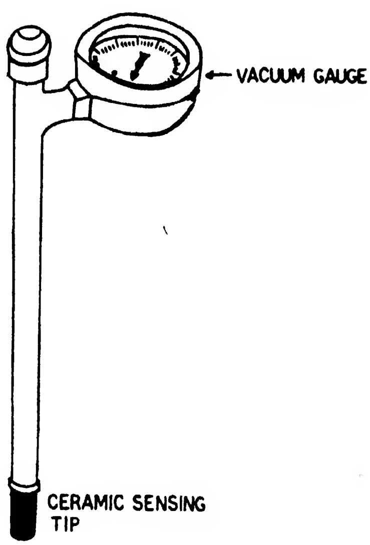


FIG. 7.3 TENSIOMETER

4.2 Standardisation

Boil some distilled water and allow it to cool in a completely filled and tightly stoppered bottle. This process drives away any dissolved air present in the water. Fill the tensiometer upto the brim with this de-aerated cool water and then close the open end of the tube firmly with the help of the rubber stopper. Keep the tensiometer in a vertical position with the gauge--end upward for 3 to 4 hours so as to develop some tension in the system. When the gauge shows a value of 0.50 - 0.60 atmospheric tension, open the rubber stopper and refill the tensiometer body upto the brim with de-aerated water and then again close the system with rubber stopper. This double priming of the instrument ensures the removal of air bubbles entrapped within the tensiometer body and thus correct tension values are obtained. While fixing the rubber stopper on the tensiometer body, one should be careful to see that no air bubble is entrapped between the water meniscus and the rubber stopper. Keep again the tensiometer in a vertical position with the gauge-end upward for a few hours till the gauge shows tension value between 0.80 and 0.85 atmosphere. This, in other words, indicates the air entry or leak value of the ceramic cup of the instrument and also tells about the higher limit of soil moisture tension, the instrument will faithfully read. Now dip the ceramic cup of the tensiometer in about 5 cm deep water in a bucket while keeping the instrument in a vertical position. The gauge pointer should indicate 'zero' within 30 to 60 minutes. Keep the tensiometer cup immersed in water till the instrument is installed in the field.

4.3 Installation

When installing the tensiometer, it is important that good contact be made between the cup and the soil so that approach to equilibrium is not hindered by contact impedence. It is always better to have a hollow tube slightly smaller than the tensiometer diameter with a cutting edge on one end, to make the hole. Then the tensiometer should be pushed slowly into the hole. The gap around the tensiometer hole may be filled with powdered soil. If the hole is made by an auger larger than the diameter of the tensiometer, the compaction of the soil after putting the tensiometer should be done very carefully so that the compaction becomes almost natural to the surrounding soil.

It is desirable to place the tensiometer cup within the zone of maximum root activity so that it will be most sensitive to any change in soil moisture. The depth of the porous cup is best taken as the distance from the centre of the cup to the surface of the soil.

4.4 Calibration

A tensiometer is calibrated against moisture percentage by installing it in the field and then recording tension readings and soil moisture content by the gravimetric method.

4.5 Choice of site

When choosing the site, it is important to select a position that is representative of the whole area which it is desired to cover.

5. *Soil thermometer (Fig. 7.4)*

5.1 Introduction

The temperature of the soil layers is of particular importance in plant growth and development.

The surface of the ground is warmed up by insolation during day time and cooled down during night time. This heating and cooling tendencies are propagated downwards slowly into the deeper soil layers. The soil temperature is maximum at the surface. It decreases very rapidly with depth.

The maximum temperature of the surface layers occurs at noon while for deeper layers it occurs in the afternoon. While the diurnal variation of soil temperature is negligible at a depth of 30 cm or more, the annual or seasonal variation of soil temperature becomes negligible only at much greater depth.

5.2 Description of the soil thermometers

The type of thermometer used for this measurement is shown in Fig. 7.4. AB is the instrument where B is the bulb end. The portion CB is embedded in the soil while the portion AC constitutes the graduated stand of the instrument which is supported on an iron stand DDEF. The bulb rests horizontally in the soil and the stand is inclined at an angle of 120° with the ground surface thus facilitating the reading of the temperature without any strain to the observer.

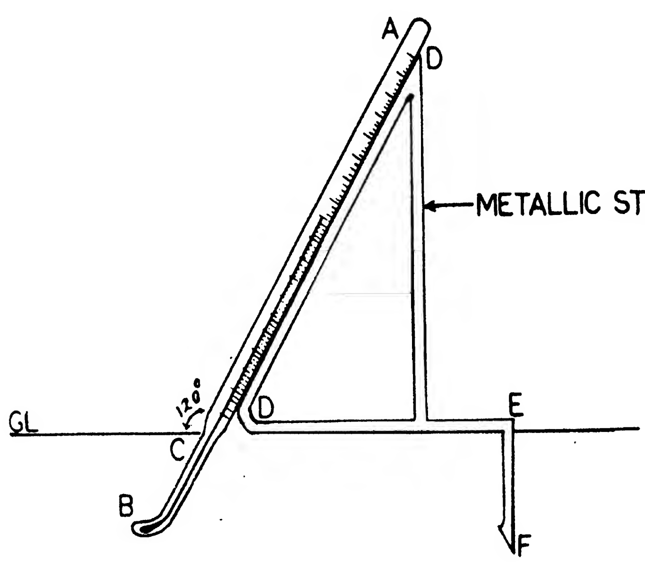


FIG. 7.4 SOIL THERMOMETER

5.3 Range

The range of the thermometers now manufactured in India is -20 to 65°C. The depths at which the temperature is to be recorded has been recommended as 5, 15 and 30 cm. The lengths of the portion CB are 9, 22 and 35 cm for 5, 15 and 30 cm depths, respectively.

5.4 Site for installation

A plot inside the observatory enclosure measuring 2 m by 1.5 m with the longer side running East to West should be selected. This plot should be on level ground. The side should be free from obstructions like building and other installations. The site should be fenced.

5.5 Installation

The metallic stand of the thermometer is fixed into the ground along a line inside the plot paralled to and 40 cm away from the Northern side of the plot. The stands are fixed 45 cm apart from each other with the upper end of the arm DD inclined towards the North.

The pit of each thermometer is dug in front of its southern side. The depth of each pit should be 5, 15 and 30 cm respectively. The size of the pit should be such that the bulb rests horizontally and the stem fits properly with DD. After installation of the thermometer in position with respect to the stand, the soil removed during digging, should be replaced layerwise carefully and be compacted suitably. It is very important to see that the bulb of the thermometer rests in good contact with the firm soil below.

5.6 Recording of the readings

The instruments should be read daily at 0700 and 1400 hours local time. While taking the reading the line joining the eye of the observer and the top of the mercury column should be at right angle to the instrument.

6. Raingauge (Fig. 7.5)

6.1 Introduction

The raingauge (FRP) recommended by Indian Meteorological Department consists of a collector with a gun metal rim base, a polythene bottle and a graduated measuring cylinder, (Fig. 7.5). The gauge is made of fibre glass re-inforced polyster. It is installed at a standard height of 30 cm from the ground level.

For North-East Indian tea region, the raingauge with 200 sq.cm collector and a 4-litre bottle having a capacity of 200 mm rainfall, is the most common, because the catch in 24 hours is not expected to be more than 200 mm.

6.2 Site for installation

The raingauge should be installed on a level ground and not upon a slope or terrace and never on a wall or a roof. The distance between the raingauge and the nearest object should not be less than twice the height of that object above the rim of the gauge.

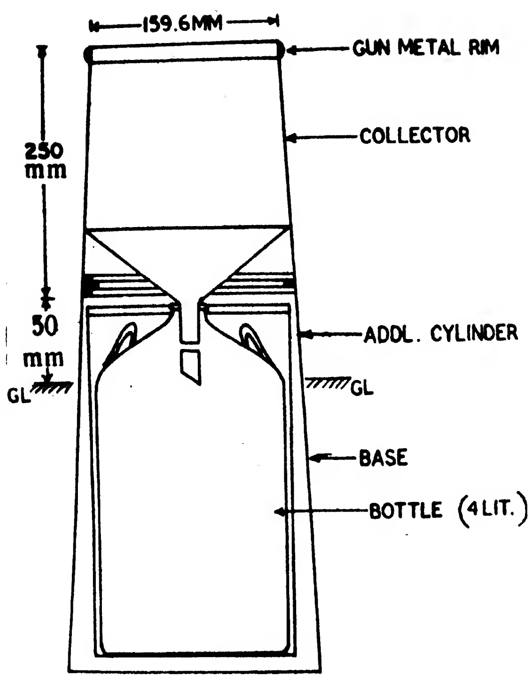


FIG. 7.5 RAINGAUGE

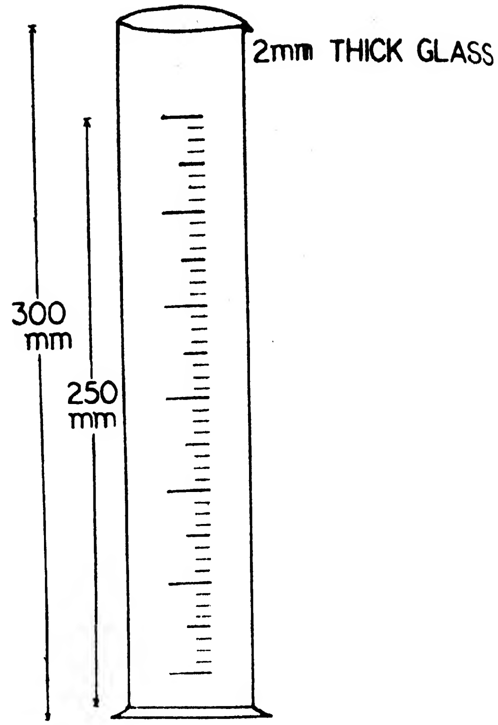


FIG. 7.6 CYLINDER FOR MEASURING RAINFALL

6.3 Measurement of rainfall and the rain measuring cylinder (Fig. 7.6)

The amount of rainfall collected by the gauge is measured with a graduated measuring cylinder, (Fig. 7.6). It must be ensured that the correct type of cylinder is used for the type of raingauge. The measuring cylinders are graduated such that one small division is equivalent to 0.2 mm of rainfall and one big division 1, 2, 3 etc. as marked in Fig. 7.6 is equivalent to 1, 2 & 3·····mm of rainfall. Reading should always be estimated to the nearest 0.1 mm.

If there is more water in the bottle than the cylinder can hold, a number of measurements may be made and the sum total of all these measurements will give the total amount of rainfall. The routine time for rainfall observation all over the country is 0830 hours IST.

6.4 Installation (Fig. 7.7)

The raingauge should be fixed on a concrete foundation (60 x 60 x 60 cm) sunk into the ground. The base of the gauge should be embedded in the foundation in such a way that the rim of the gauge is exactly 30 cm above ground level. Extreme care should be taken to ensure that the rim of the gauge is perfectly level. It is also important that the gauge is firmly secured to the foundation. The relative position of the collector and the base should be such that when correctly assembled in position the collector can be locked to the base by an external locking device.

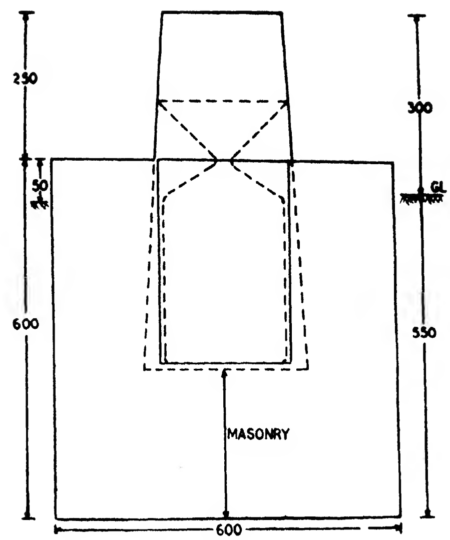


FIG. 7.7 INSTALLATION OF RAINGAUGE
(all figures are in mm)

6.5 Maintenance and care of the raingauge

(a) the raingauge should never be painted and all the parts must be kept clean and free of dust,

(b) while replacing the collector on the base after recording, it should be ensured that the two locking rings have engaged properly,

(c) care must be taken not to dent or deform the gun metal rim of the collector,

(d) the nearest area surrounding the raingauge should be kept clear of any vegetative growth.

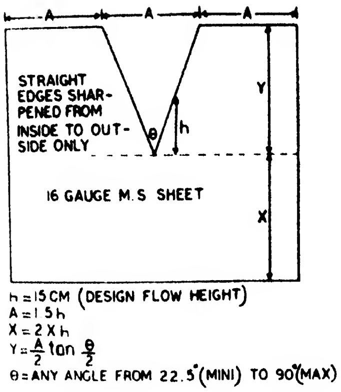
7. V-notch weir (Fig. 7.8 & 7.9)

7.1 Introduction

The measurement of water is important in drainage studies since it is necessary to know the quantities of water that flow out of a drainage basin or alternatively it may be desirable to make measurements of the flow from an open channel or a drain pipe.

A weir is a notch of regular form through which water may flow. There are a number of different types of weirs and they are classified according to the shape of the notch, for example, V-notch weir, rectangular weir etc.

The weir, if properly constructed and installed, is one of the most simple and accurate methods of measuring discharge rate.



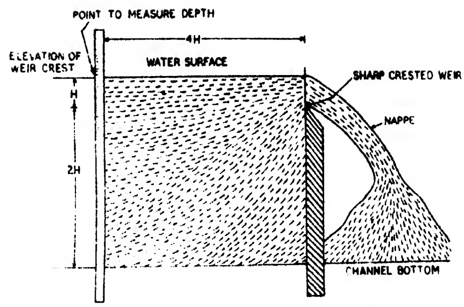


FIG. 7.8 DIMENSIONS OF V-NOTCH WEIR FIG.7.9 INSTALLATION OF V-NOTCH WEIR

7.2 90° V-notch weir

The 90° V-notch weir is commonly used to measure small flow accurately. The discharge through a 90° V-notch weir may be computed by the following formula:

$$Q = 0.0138\ H^{2.5}$$

in which,

Q = discharge, l/s
H = head, cm

To ensure reliable results in measurements, the following precautions are necessary in the use of 90° V-notch weirs.

(a) The weir should be set at lower end of a long pool sufficiently wide and deep to give an even, smooth flow of a stream. Baffles may be put in the wider pond to reduce the velocity of approach and equalise the flow. To measure the discharge from pumps a portable weir pond made of sheet metal or a build-in weir pond made of brick or stone masonary is constructed and the weir plate is fixed at its outlet.

(b) The V-notch must be vertical.

(c) The centre line of the weir should be parallel to the direction of flow.

(d) The apex of the V-notch should be above the bottom of the approach channel (weir pond) at least about twice the depth of water flowing over the weir.

(d) The apex of the V-notch is placed high enough so that water will fall freely below the weir, leaving an air space under the overfalling sheet of water.

(f) The scale or gauge used for measuring the head should be located at a distance of about four times the approximate head. It should be far enough to one side so that it will be in a comparatively still water. The zero of the scale should be exactly on the same level with the apex of the V-notch weir.

8

ESIGN OF PUMP OUTLET FOR LOW LANDS HAVING RESTRICTED DRAINAGE OUTLETS

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Introduction

Outlet is a key factor in the success of drainage system. The outlet must be deep and large enough to meet the drainage requirement of the waterlogged area. The size of outlet shall be according to the area of watershed, frequency of flood, land topography, general hydrology of the area and soil properties.

Type of outlets

The main types of outlets for drainage system are:

1. Gravity outlet (natural)
2. Pump outlet (artificial)

1. Gravity outlet

A gravity outlet is one in which the water flows out of the drainage system by gravity into a natural stream, open drain, a lake/pond or a down well. The topography of the land as well as the permeability of the soil dictates the choice of an outlet. The gravity outlet means that the elevation of outlet is adequate to collect water from main drains without any back pressure. If there is a danger of flood water backing up into the main drain, an automatic flood or tide gate needs to be installed in place of sluice gate.

Requirement of a good outlet

The importance of good outlet is indicated by the fact that a high percentage of failures of drainage system is due to faulty outlets. The requirements of a good outlet are:

i) to provide a free outlet with minimum maintenance,

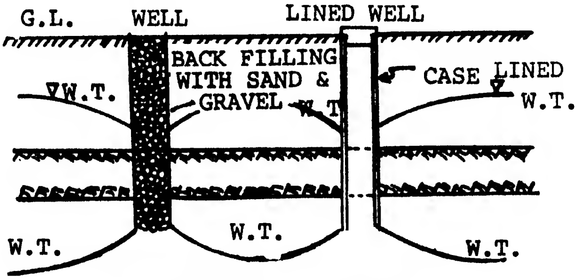
ii) to dispose the outflow without erosion,

iii) to prevent the backflow of flood water into the main drain.

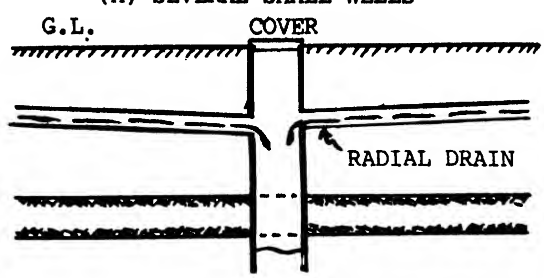
2. Downwell (Fig. 8.1)

Down wells or Down-Draining wells or Vertical Drainage wells are not commonly used. Their use is limited to areas of porous material such as fractured lava or porous lime stone underlying the soil. If a very impermeable subsoil is underlain with permeable sands and gravels, it may be practical to penetrate the impermeable stratum with a well which will permit water to drain from the surface into the underlying gravels. A number of small wells may be used or a single large well may take the discharge of main drains. The wells may be left open and cased with bricks or it may be in-filled with gravel or crushed rocks.

The existence of a substratum that can continually take in large quantities of water and that can be reached without prohibitive cost is the exception rather than the rule. Since there is no positive method for locating or for predicting the permanent capacity of such outlets, their use involves considerable risk. But in some conditions, down wells can effectively drain the land.



(A) SEVERAL SMALL WELLS



(B) SINGLE WELL WITH RADIAL DRAINS

FIG. 8.1. DOWN-WELL FOR DRAINAGE

3. Evaporation sumps

In some areas, there are no streams/rivers etc. that can take the drainage water. Under these circumstances, the use of evaporation sumps may be helpful. Consideration is given to the rate of evaporation in the area in designing the sump. The rate of evaporation from the sump shall nearly be equal to the rate of inflow of drainage water plus the rainfall that falls on the sump.

4. Pump outlet

Pumps may be used for disposal of water from drainage systems where discharge by gravity flow cannot be obtained because of inadequate outlets or because of backwater from tidal flooding (Fig. 8.2). The requirement for planning, designing and constructing pumping facilities do vary substantially from site to site. Planning requires consideration of the entire drainage system served so that diversion, storage areas, open channels and outlets are used to best advantage in determining capacity, size and operation of the pumps.

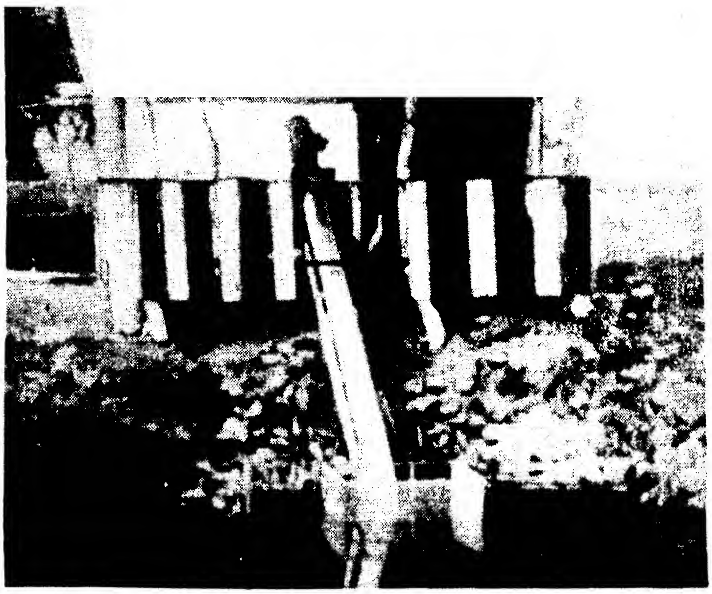


FIG. 8.2 PUMP-OUTLET

The design requires consideration in regard to:

(i) type, (ii) size, (iii) capacity of pumps, (iv) kind of power to be used, (v) shape, size and depth of the sump, (vi) no. of pumps, (vii) pumping duration etc. (viii) location of pumping plant for an effective outlet of the entire drainage system and (ix) the required water removal rate with due consideration of crop requirement.

(a) Need for pumping

The flat-low lands in various parts of N.E. India require pump outlet. Due to the blockades raised by paddy growers and busti people for fishing and irrigation purposes, encroachment of the river banks and waterways, construction of raised P.W.D. roads and railway lines with highly inadequate number and size of culverts, and allotment of low lands to people in unplanned manner have been some of the main factors responsible for having pump outlet now. The time is not far, when many more tea gardens will have to go for pump outlet if the things continue to be in current manner.

(b) Location of pumping plant

A wet area may be served by one or more pumping plants. Large areas with widely separated outlets may justify more than one pump. The pumping plant location is determined by :

i) topography,

ii) groundwater conditions,

iii) accessibility of power line and fuel supply roads,

iv) protection from vandalism.

Normally, the site will be at the lowest elevation of the area to be drained and near to the best possible outlet.

In order to minimise the amount of water to be pumped, the runoff from all areas that can be drained by gravity should be diverted from the area served by the pumps. When practical, the lower reaches of the main drains shall be used as temporary storage. This will permit a reduction in the size of the pumping unit and may also provide more constant operating conditions because of less fluctuation in the water stage.

(c) Pumping plant capacity

The capacity selected for the pumping plant should give consideration to such factors:

i) size of the area served,

ii) amount, rate and timing of rainfall and runoff,

iii) groundwater condition,

iv) seepage rates.

Pumping plant capacity is usually determined on a daily rate basis so that for surface drainage system the required capacity can be determined as the runoff from a 24-hour rainfall of a selected frequency of occurrence, plus base flow, minus allowance for available surface and groundwater storage. Rainfall periods exceeding 24-hours may need to be considered in evaluating available surface and groundwater storage. For small areas upto 1.6 sq.km., therefore, the amount of water to be pumped should be about the same as would be required for a gravity drainage system with free outlet.

Usually 3 to 5 years **R.I.* is ample for tea lands.** The required pumping capacity should be equal to the optimum runoff obtained from such precipitation in a 24 hour period.

$$Q = P - R_s - S_g - S_d - S_f + q$$

where:

Q = Runoff to be removed in 24 hours,
P = rainfall from 24 hour - storm for the selected R.I. (5 years),
R_s= direct surface runoff in 24 hours,
S_g= temporary ground storage,
S_d= temporary drain storage,
S_f= temporary forebay storage,
q = seepage flow into the area.

Where direct entry of surface water can be excluded, pumping plant capacity can be determined as the design capacity of a subsurface gravity

R.I.* = Recurrence Interval

drainage system plus some allowance for flows that may occur in excess of the design rate. Experience has shown an allowance of 20% as enough. Thus:

$$Q_p = 1.2\ Q_g$$

where:

Q_p = pumped discharge capacity,

Q_g = gravity discharge capacity.

(d) Selection of pumps

In selecting drainage pumps, consideration must be given to the Type, Characteristics, Capacity, Head and Number. The drainage pumps must operate efficiently while pumping large quantities of water at low heads and also may be required to handle substantial amount of sediments and trash in the water. For these reasons either Axial-flow (propeller) or Mixed-flow pumps are commonly used. Figure 8.3 may be followed in selecting the appropriate size of pump.

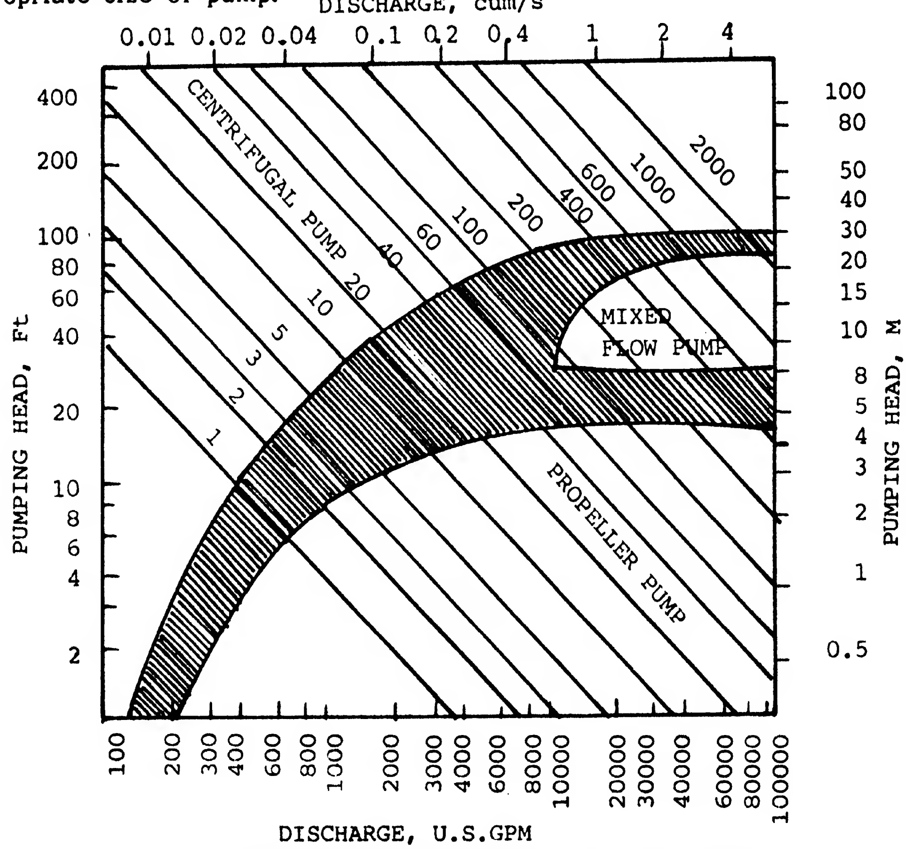
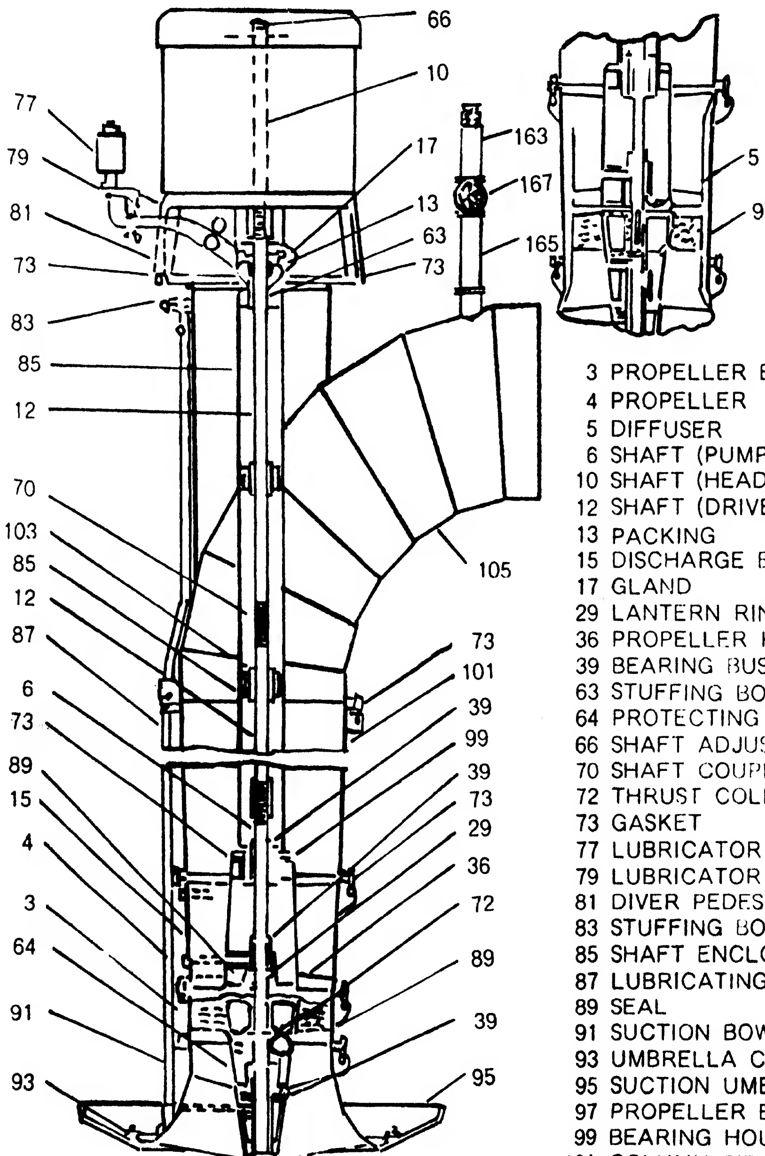


FIG. 8.3 PUMP SELECTION CHART (U.S.S.C.S.,1973)

(i) Axial-flow pump

These pumps work well for dynamic head of 1 to 5 metres, speed of 450 to 1850 R.P.M. and discharge capacities upto 6,000 litres per second. The vertical, fixed-blade, single-stage pump is applicable to most drainage

system requirements. These pumps are simple in construction, low in cost, require no priming at heads less than 3 m, require a minimum amount of floor space and housing. Because of their high speed, axial-flow pumps can utilise less costly, high speed motors or engines. (Fig. 8.4).



3 PROPELLER BOWL
4 PROPELLER
5 DIFFUSER
6 SHAFT (PUMP)
10 SHAFT (HEAD)
12 SHAFT (DRIVE)
13 PACKING
15 DISCHARGE BOWL
17 GLAND
29 LANTERN RING
36 PROPELLER KEY
39 BEARING BUSHING
63 STUFFING BOX BUSHING
64 PROTECTING COLLAR
66 SHAFT ADJUSTING NUT
70 SHAFT COUPLING
72 THRUST COLLAR
73 GASKET
77 LUBRICATOR
79 LUBRICATOR BRACKET
81 DIVER PEDESTAL
83 STUFFING BOX
85 SHAFT ENCLOSING TUBE
87 LUBRICATING LINE GUARD
89 SEAL
91 SUCTION BOWL
93 UMBRELLA CLAMP
95 SUCTION UMBRELLA
97 PROPELLER BOWL LINER
99 BEARING HOUSING
101 COLUMN PIPE
103 CONNECTOR BEARING
105 DISCHARGE ELBOW
163 VACUUM BREAKER CAP
165 VACUUM BREAKER PIPE
167 VACUUM BREAKER VALVE

FIG. 8.4. AXIAL FLOW PUMP (USDA, SCS, No. 16)

(ii) Mixed-flow pump

Mixed-flow pumps (Fig. 8.5) develop flow which is partially radial and partially axial. These pumps operate more efficiently over a wide range of head i.e. 3 to 30 metres. These pumps can also handle silt and small trash. They permit shallower and less costly excavations and sumps but are more costly and require priming at high heads.

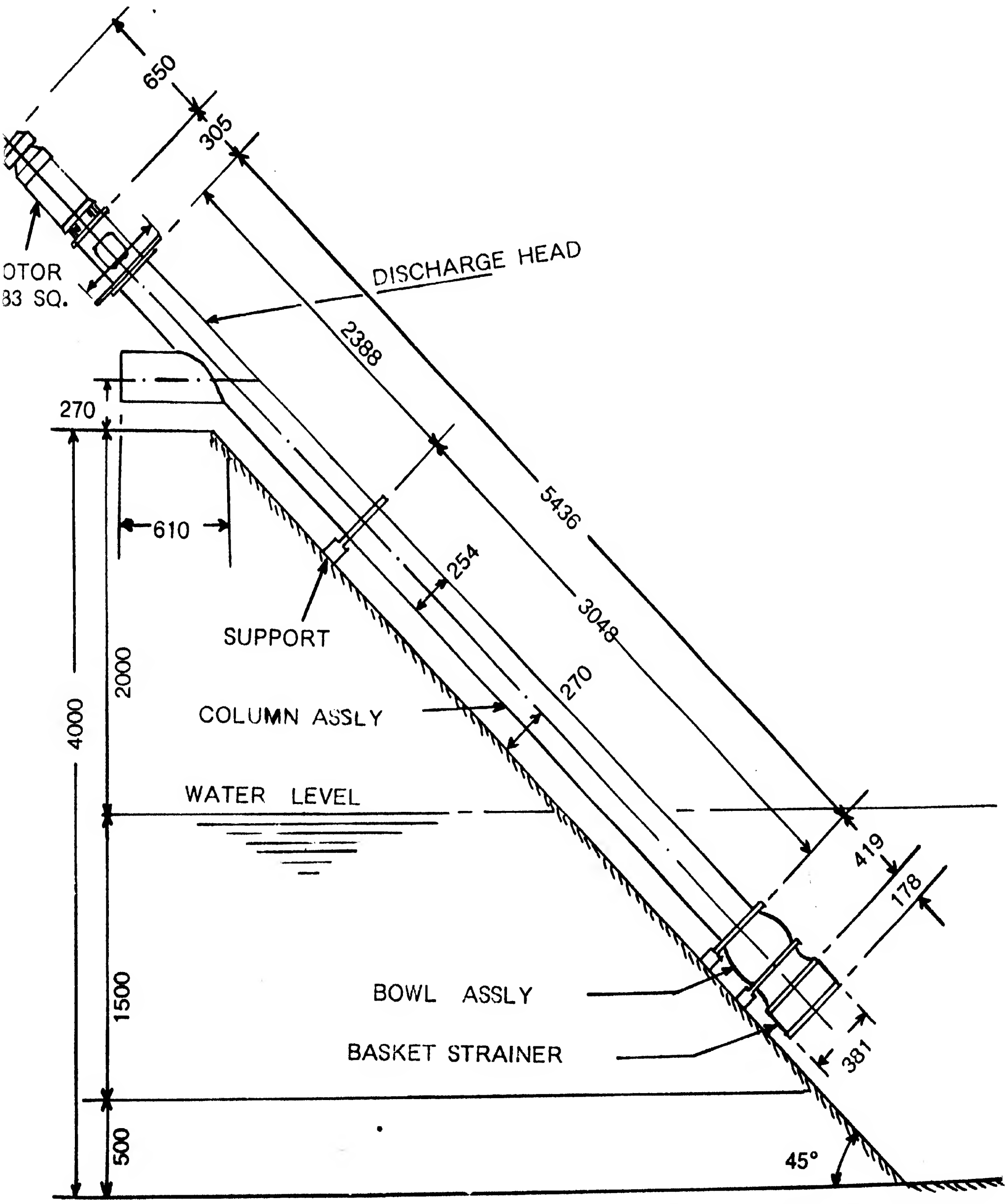


FIG.8.5. MIXED-FLOW INCLINED PUMP WITH VERTICAL HOLLOW SHAFT MOTOR

(e) Number of pumps

The size and number of pumps are determined from the required plant capacity. For small watersheds, the total requirement can be handled by one pump. For large water-sheds, it is advantageous to have two or more pumps to provide efficient pumping over a wider range of pumping rates. In a plant with two pumps, the most desirable range of pumping rates is obtained when one pump has about half the capacity of the other. When three or more pumps are used, equal capacity of all pumps is considered most satisfactory.

While surface and subsurface flow are to be pumped, one pump should be selected for efficient operation at the head and discharge required for pumping subsurface flow. In any case, it is desirable that the size of one pump is such that it can operate continuously over comparatively long periods without frequent starts and stops. A pumping plant layout is shown in Fig. 8.6.

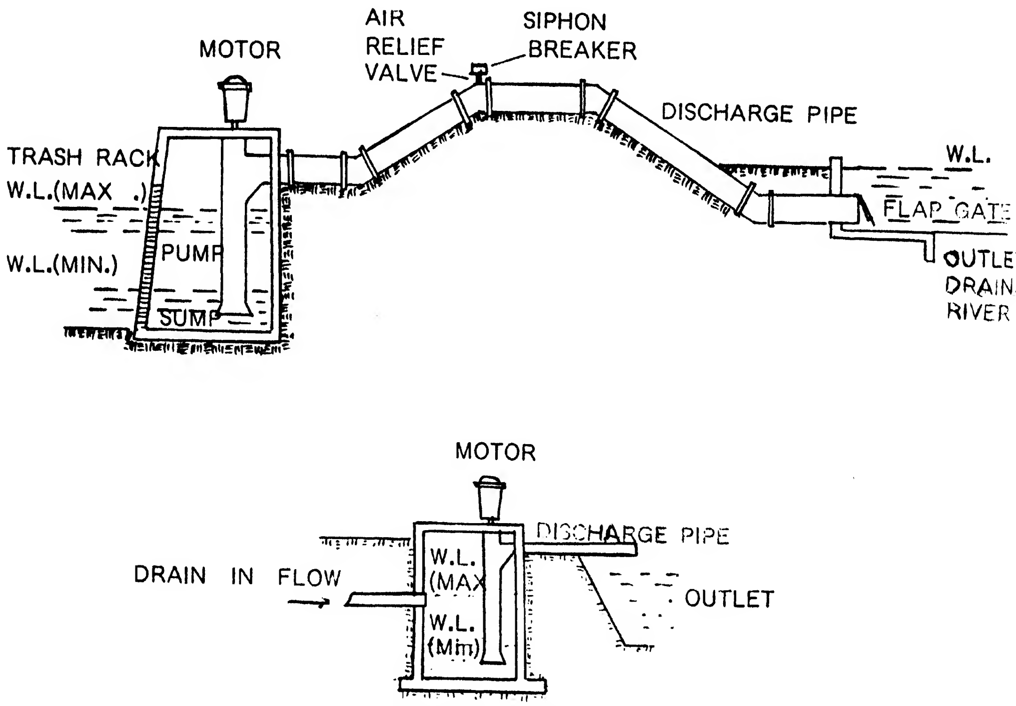


FIG. 8.6. PUMPING PLANT LAYOUT

(f) Pump size

The pump size should be based on heads and speeds when the pumps are operating at or near maximum efficiency. Discharge velocities under these circumstances will vary between 2.5 and 4.0 m/sec for a properly sized pump

$$\text{Pump size} = \frac{\text{Required capacity}}{\text{Discharge velocity}}$$

(g) **Power and drives**

Both electric motors and internal combustion engines are used as power units for drainage pumps. Electric motors are preferred because of their simplicity and low upkeep. Vertical types are most suited. Squirrel-cage (induction) motors are more common in use due to their low costs as compared to synchronous motors. Starting torques of Mixed-flow and Axial-flow pumps are high. Therefore, capacitors shall be installed in the motors to adjust the incoming line voltage drop.

Power requirement

$$WHP = \frac{Q \times H}{76}$$

$$BHP = \frac{WHP}{\text{Motor Effy} \times \text{Pump Effy} \times \text{Transmission Effy}}$$

K W input to motor = BHP X 0.746

(h) **Sump dimensions**

Sumps may range from large tanks for handling big quantities of surface and subsurface water to small sumps to handle small flow from subsurface drains. The sump entrance must be large enough to pass the design discharge to the pumps without much restriction. The sump storage for pump should be sufficient to prevent excessive starting and stopping of the pumps. Storage requirement depends on pumping rate and frequency of cycling. When the inflow is less than the pumping rate, cycling will occur. For manually operated pumps, the number of stops and starts should not exceed two or three cycles per day. For automatically operated pumps, even 10 to 15 cycles can be accepted.

$$\frac{3600}{N} = \frac{S}{Q_p - Q_i} + \frac{S}{Q_i}$$

Where:

N = No. of cycles per hour
Q_p = Pumping rate, cum/sec
Q_i = Inflow rate, cum/sec
S = Storage volume, cum

At maximum storage:

$$Q_i = \frac{Q_p}{2}$$

and $$S = \frac{900\ Q_p}{N}$$

Generally, sump size should be such as to provide at least 60 cm depth between starting and stopping levels of pump.

Experimental Findings

An experiment on drainage and pump-outlet system was conducted in a tea garden (Kalabari Rangati T.E., West Bengal) during 1982 to 1985. The site is 88°55' E longitude and 26° 50' N latitude at about 190 m elevation above m.s.l. The drainage system was designed based on soil, crop, climate and hydrological data as discussed below.

Soil

The soil of the project area belongs to medium texture. Soil profile studies were conducted and the results are given in Table 8.1. The land topography is more or less flat with mild uniform slope in East-West direction (0.5%).

Table 8.1 : Soil Data

Particulars	Value
Texture	Sandy loam (Sand : 70%, Silt : 22%, Clay : 8%)
Depth : Top Soil	60 cm thick
Sub Soil	200 cm thick
Colour	Brown
Structure	Granular
Hydraulic conductivity	2.40 m/day
Infiltration rate	20 mm/hour
Depth of impervious layer	10 m
Drainage coefficient	8 mm/day
Land slope	0.40% in N-S directions 0.50% in E-W directions
pH	4.5 - 5.0
% Carbon	0.5 - 1.30
% Nitrogen	0.082
P_2O_5	25 ppm
K_2O	45 ppm

Climate

The normal annual rainfall of the project site is 4560 mm. The highest rainfall was received in 1984 (5225 mm) and the lowest in 1982 (3832 mm). Monthly distribution of rainfall for the period 1979 to 1984 is given in Table 8.2.

Table 8.2 : Monthly distribution of rainfall, mm

Month	1979	1980	1981	1982	1983	1984
January	16.51	-	27.69	-	3.05	65.28
February	21.59	47.24	-	1.02	17.53	37.59
March	-	100.84	140.97	72.14	47.14	9.14
April	175.01	103.38	204.22	239.78	231.39	300.74
May	210.82	433.58	392.94	261.87	263.40	772.67
June	429.51	843.79	946.66	1037.08	1132.08	959.61
July	1649.22	1137.92	1200.40	1454.66	1582.93	1246.63
August	1002.79	983.49	690.37	296.67	750.06	370.58
September	776.22	893.57	690.37	393.45	808.48	1078.23
October	698.25	160.53	1.27	39.62	174.24	362.02
November	46.99	-	-	30.23	-	-
December	48.51	-	7.62	5.08	28.19	12.70
Total:	5075.42	4704.34	4302.51	3831.60	5038.49	5215.19

The data show that about 92% of the total annual rainfall is received during 6 rainy months (May to October) and 8% in remaining 6 winter months i.e. November to April. Normally, July is the heaviest rainfall month which receives about 25 to 30% of the total annual rainfall i.e. 1200 to 1650 mm.

Crop

The crop yields were showing a steep declining trend since 1979. The rate of decline in yield was 5.5% in 1980 and 19.3% in 1981 over 1979 yields. The average yield level of experimental area was about 100 kg/ha less than that of area taken as 'control' in the studies. The data on yield are given in Table 8.3 for the period 1979 to 1981, i.e., pre-experimental period.

Table 8.3 Yield (Made Tea, kg/ha) for the pre-experimental period

Year	Experimental area (113 ha)			Control plot (175 ha)		
	% area under L.P.s	yield, kg/ha	% Decrease over 1979	% area under L.P.	Yield, kg/ha	% Decrease over 1979
1979	26	1808	-	33	1893	-
1980	61	1709	5.5	19	1795	5.2
1981	9	1460	19.3	32	1586	16.6

The estate produced record crop in 1979 in the history of the garden. Due to heavy and prolonged waterlogging, the tea roots have been very shallow (30-45 cm) and inadequate in volume. The roots had tendency to grow horizontally or even upward. The root lenticels were found enlarged confirming waterlogging. Most of the weeds growing in the area were of waterlogging and aquatic types. The tea plants were prone to heavy infestation of black rot, red rust and violet root-rot diseases. The crop response to soil applied fertilizers was extremely poor.

The experiment was taken up with the main objective of arresting the declining trend in tea yields and to reverse it by way of improved drainage alone keeping all other inputs more or less the same as before.

General hydrology

The area receives very heavy rainfall (5000mm). In its north (high side), there is large area under paddy cultivation, which remains full of water during rainy season. A considerable amount of surface runoff and subsurface seepage water flows through the estate causing serious waterlogging during rainy season. There are some natural springs in the project area; some of which flow on the ground surface almost all throughout the rainy season. As a result, the general groundwater table of the area remains very high (40 - 60 cm below ground surface) most of the time.

A big river (Diana) flows along the western boundary of the estate. Flood control department has constructed an embankment along the garden boundary for flood protection, which has blocked the drainage outlets of the garden completely. During rainy season, a considerable amount of seepage from another river flowing close to the eastern boundary of the estate moves into the garden and further adds to the problem of waterlogging.

Old (conventional) drainage system

The estate followed the concept of only surface drainage and had the network of drains as given below. The old conventional drainage system was maintained in its original form in the control plot (175 ha) for comparative studies.

Runoff drains : 45 cm deep, 30 to 60 cm wide, vertical wall open drains at 12 m spacing in both North - South and East - West directions. The total length of runoff drains was about 1600 m per ha.

Collector drains : 60 cm deep, 75 to 90 cm wide, vertical wall, open drains at 50 m spacing in both North - South and East - West directions. The total length of collector drains was about 400 m per ha.

Main drains: 75 to 90 cm deep, 100 to 150 cm wide open drains at 300 m spacing in East - West direction.

The drain juctions, bed gradients and their alignment was improper. As a result, the drains used to remain full of water during rains and were subject to collapse and caving-in problems.

Improved drainage system

The old drainage system was finished-off and new drainage system was designed using Hooghoudt's equation and installed in the experimental area (113 ha) having tea plantation of the same type as of control plot.

Lateral drains: Parallel lateral drains in East - West direction, 105 cm deep, 45 cm wide at top, 20 cm wide at bottom, at 30 m spacing in gridiron pattern. Length of each lateral was 100 m and the bed gradient was 0.40%. Total length of laterals was 335 m/ha.

Submain drains: 120 cm deep, 120 cm wide at top, 75 cm wide at bottom at 100 m spacing in North - South direction. The bed gradient was 0.30%.

Main drains: 150 cm deep, 200 to 240 cm wide at top, 100 cm wide at bottom at 200 m spacing in East - West direction. The bed gradient was 0.40%.

Interceptor drains: 150 cm deep, 180 cm wide at top, 90 cm wide at bottom. It was installed along the northern boundary of the tea estate in East - West direction to cut-off the seepage flow entering into the area from adjacent high paddy lands. The layout plan of drainage system is shown in Fig. 8.7.

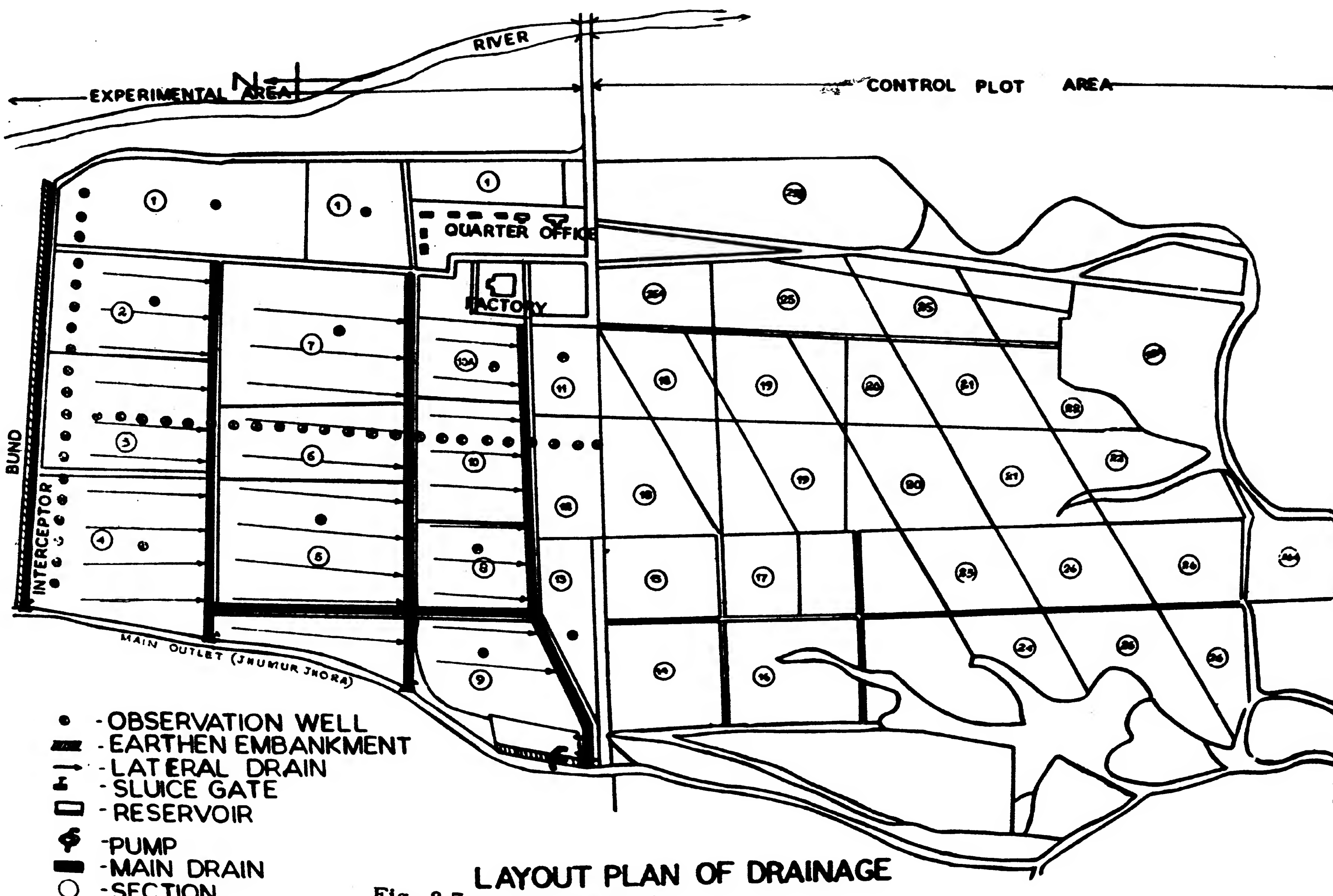


Fig. 8.7 LAYOUT PLAN OF DRAINAGE EXPERIMENT

Pump-Outlet

The technical information on pump-outlet is given in Table 8.4.

Table 8.4 Technical information on pump-outlet system

Make	:	Johnston
Type	:	M-F inclined pump
Size	:	381 mm dia, single stage
RPM	:	1460
H.P. requirement	:	12.50
Capacity	:	150 l/sec. at total head = 5m
No. of pumps	:	One
Source of power	:	Overhead electric supply, A.C., 3-phase, 30 amps, 420-380 volts, 50 cycles, 1.24 km long line.
Motor	:	Kirloskar make, vertical hollow shaft, squirrel cage, induction motor rated 380 volts, directly coupled with pump, HP = 15, RPM = 1460
Sump	:	30m x 20m x 4m
Sluice gates	:	4 Nos. 100 x 100 cm, mild steel sheets, 8 gauge, vertical movement.

The design criteria for pump outlet was estimated to be 8mm/day. The system included a pumping plant, a sump, 4 sluice gates, one flap-gated structure and trash-traps. The pumping point was electrified and designed in such a manner that the pump could be operated easily without having provision for a step-up transformer. The electric motor on the pump was rated 380 volts (420 volts minus line drop). The pump of specifications shown in fig. 8.5 was installed with a sump (Fig. 8.8)

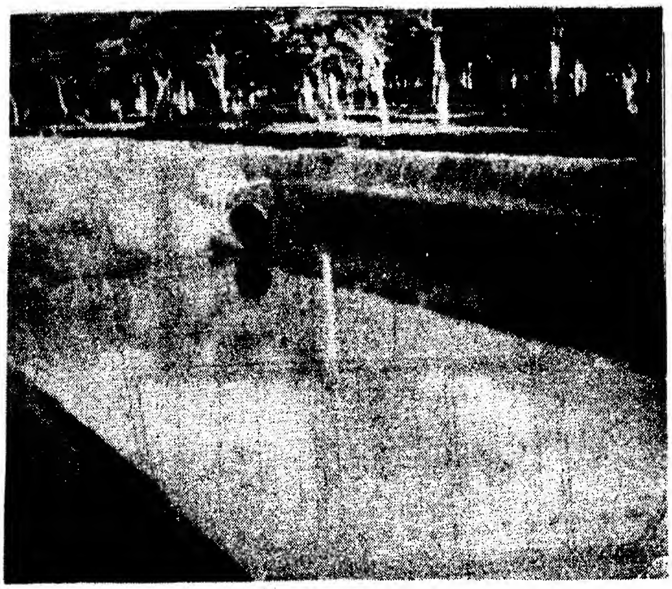


Fig. 8.8

Agronomic practices

The estate followed Tea Research Association's standard recommendations on manuring, weed control, pest control, plucking and pruning. The estate applied N:P:K at an average rate of 100:0:60 kg/ha as ground application and 4 rounds of foliar application of urea and zinc at the total concentration of 4% (2 + 2%) at fortnightly intervals starting from June. The shade status in the experimental and control plots was more or less the same. Plucking of tea leaf was done regularly at 8 - 10 days intervals.

Water table investigation

To have a detailed study of groundwater table behaviour in relation to rainfall, 53 piezometer wells were installed to a depth of 270 cm below the ground surface to have a comprehensive coverage of the entire project area. The water table data in the experimental and control plots were recorded using an "Electronic Water Table Recorder" designed and fabricated locally by us. The water table profiles are presented in Fig. 8.9 and 8.10 and the electronic water table recorder is shown in Fig. 8.11.

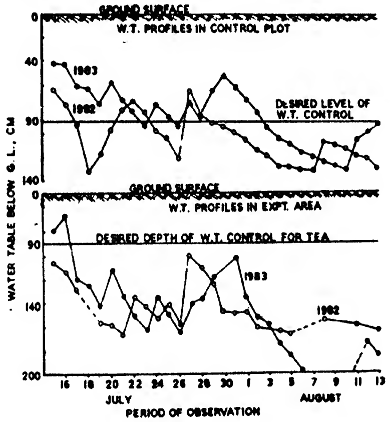
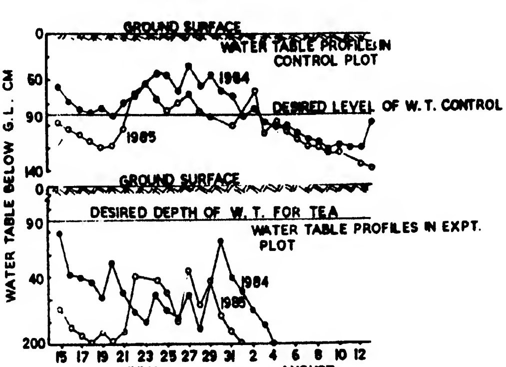


FIG.



WATER TABLE PROFILES IN CONTROL PLOT & EXPERIMENTAL AREA

FIG.

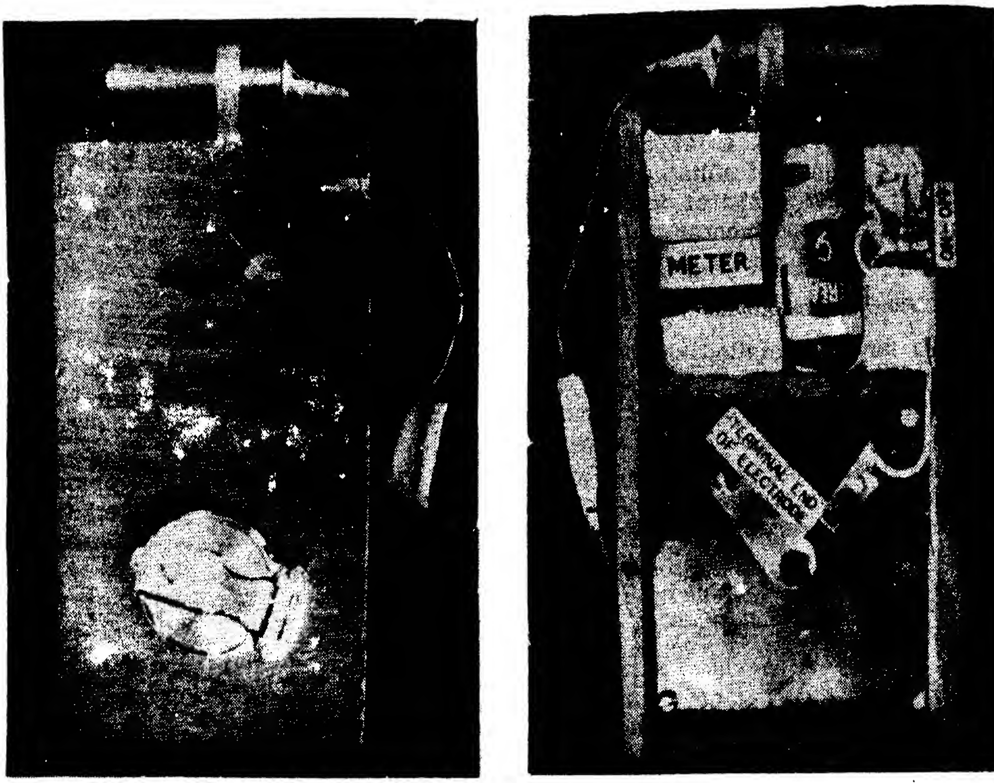


FIG.8.11. ELECTRONIC WATER LEVEL RECORDER DESIGNED & FABRICATED IN THE DEPT.

RESULTS AND DISCUSSION

Prior to drainage improvements, the estate was observing a steep declining trend in crop yields since 1979. The piezometric data showed a serious build-up of water table in the rootzone of tea plants all throughout the rainy season (July to October). The water table was observed to rise as close as 40 cm to the ground surface. It, however, fluctuated from 40 to 100 cm depth, most of the time. The old experiments have revealed that if water table rises into 90 cm zone below ground surface and remains there for longer than 72 hours, the tea rooting system gets severely damaged and as a result there is marked depression in the yield. This fact is again confirmed by shallow and inadequate rooting system of tea plants observed in the project area. The studies showed that the tea roots were hardly 45-50 cm deep. The roots were badly twisted and bent. Their tendency was to grow horizontally or even upward for want of O_2. About 1% of mature tea plants were dying every year due to various soil borne diseases caused by water-logging. The response to ground application of fertilisers was poor.

The drainage experiment was taken up in 1982 with an objective to control the water table below the tea rootzone during rainy season. The data on crop yields, rainfall and water table were recorded.

Water Table

The data plotted in Fig. 8.9 and 8.10 show that the subsurface drainage system provided in the experimental area could very effectively control the water table 90 cm below the ground level (desirable level of W.T. control for tea) all throughout the rainy season. The water table in control plot, where only surface drainage system was provided, remained in the tea rootzone throughout rainy season and at times it was as close as 40 cm to the ground surface. The high rainfall was found to be one of the major sources of excess water causing waterlogging apart from subsurface seepage flow from adjacent high paddy lands and river along the eastern boundary of the project area.

Crop yields

The yield data recorded from the experimental plot (113 ha) and control area (175 ha) are presented in Table 8.5. The data recorded from the experimental plot showed an increase of 24.9, 25.1, 38.0 and 33.9 % in 1982, 1983, 1984 and 1985 respectively over that of 1981 yields (pre-experimental year). It is worth noting that the original yield level of the area selected for drainage experiment was 100 kg/ha less than that of area taken as "control" in the present study. The poor yielding section was taken for drainage experiment to study the extent of increase in yields due to improved drainage.

Table 8.5 Tea yields as influenced by sub-surface drainage

Year	Rainfall mm	Experimental area (113 ha)			Conventionally drained area (175 ha)		
		%area under L.P.	Yield, made tea kg/ha	%increase in yield over 1981	%area under L.P.	Yield, made tea kg/ha	%increase in yield over 1981
1985	5159	33	1953	33.8	30	1674	5.5
1984	5215	33	2015	38.0	16	1867	17.7
1983	5038	40	1826	25.1	23	1870	17.9
1982**	3832	-	1824	24.9	28	1859	17.2
1981*	4303	9	1460	-	31	1586	-

The crop yield data from control plot (175 ha) showed that after an initial increase of 17.2% in 1982, the yields remained static in 1982, 1983 and 1984. There was only 8 kg/ha increase in tea yields in 1984 as compared to 1982 yields. In 1985, there has been a significant decline in yield of 193 kg/ha as compared to 1984. On an average, there has been only 88 kg/ha increase during last 4 years period in control plot as compared to base year crop of 1981. In the same period (1982-1985), the experimental area has recorded an increase of 493 kg/ha as against 88 kg/ha increase in control plot, which is highly remarkable. The area which was producing 100 kg/ha less crop in the past is now after improved drainage producing 279 kg/ha more crop as compared to yields of control plot.

This increase in yield in experimental area was obtained inspite of the fact that there was considerable increase in area under L.P. i.e. 40, 33 and 33% in 1983, 1984 and 1985 as against 23, 16 and 30% in control plot during the same period. On an average, L.P. tea sections give about 20-25% less crop than unpruned teas. Apart from increased L.P. there was 1206, 1383 and 1327 mm more rainfall in 1983, 1984 and 1985 respectively as compared to 1982 rainfall (3832 mm). The drainage system of experimental area was found

Indirect benefits

Due to waterlogging, the project area had serious infestation of rather difficult weeds e.g. narrow-leaved grasses, creapers, ferns and thatch etc. It was quite expensive and difficult to control these weeds. Because of thick grass cover on the ground, the availability of soil applied fertilizers to tea plants was also highly restricted. After drainage, the aquatic type of weeds have reduced considerably and now the broad-leaved weeds e.g. Bagracote, which are easy to eradicate, are dominating over the grasses. Now, there has been reduction of 10% in Gramoxone, 59% in 2,4-D and 78% in Dalapon consumption as compared to their consumption in 1981 (Pre-drainage year) to keep the ground weed free as before.

The estate used to apply N:P:K @ 100:0:60 kg/ha in the past. But due to various financial constraints, the estate could not apply full dose of fertilizers during 1982 - 1985. There had been a reduction of 21, 8 and 20% in N-application and 26, 5 and 10% in K-application in 1982, 1983 and 1984 respectively. Should there had been no cut on manuring, the tea yields could still be higher than that recorded during this period.

Due to various soil borne diseases caused by waterlogging, the mature tea plants were dying at a rate of 1% every year in the past. Since drainage improvements were provided, there has hardly been any loss of plant due to waterlogging in the experimental area during the period 1982-1985 whereas the plants in control plot are still dying at the same rate.

The old conventional drainage system had 1600 m long runoff drains and 400 m long collector drains per hectare which has now been reduced to 335m long lateral drains and 70 m long submain drains per ha in the experimental area. This has saved about 5 times on the annual maintenance cost of drainage system.

Cost-benefit : The drainage project was evaluated for its cost-benefit ratio. It works out to be more than 1:8 for the period of 4 years of experimentation (1982-85). This is considered as a highly favourable ratio for any developmental project.

9

DESIGN & INSTALLATION OF UNDERGROUND PIPE DRAINAGE SYSTEM

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Introduction

A subsurface drain is one that is beneath the surface of the soil. In general, the initial cost of a pipe drainage system is somewhat higher than the initial cost of an open drainage system but if one balances out the cost of land loss and cost of maintenance of open drains etc. the pipe drainage system may prove to be more economical in long run than open drainage system.

Subsurface drains drain the soil rather than the surface. They take out only the soil excess water and not the water that plants can use. That water is held by capillary. The excess water flows by gravity into the drains. Subsurface drains have definite advantages over surface drains. They occupy no land and they do not harbor weeds.

1. Drain materials

Most common materials used for pipe drains are clay, concrete and plastic.

(a) Clay pipe (tile)

Clay tiles are usually made in lengths of about 30 cm and have a range of internal diameters varying from 10 to 20 cm; 12.5 cm being the standard size for lateral drains. The tiles are straight with or without collar. The water enters the pipe line through the gap between the two tiles.

(b) Concrete pipes

Concrete pipes are used if clay tiles are not readily available or if tiles of greater diameter are required. The disadvantage of concrete pipes is that they deteriorate quickly under acid soils and soils with high sulphate content.

(c) Plastic pipes

The most common plastic pipes are PVC due to their high resistance power to outside pressure. The drain pipes can be rigid and corrugated. The corrugated pipes have great resistance to outside pressure and are comparatively cheaper than smooth plastic pipes but they have high hydraulic resistance. Smooth pipes are provided with saw-slits usually longitudinal and sometimes transverse. Corrugated pipes have many small openings in the valleys of the corrugations, as follows.

Particulars	Smooth pipe
Outside dia	90 mm with 2 mm wall thickness, 110 mm with 2.2 mm wall thickness, 125 mm with 2.5 mm wall thickness.
Perforations	25 mm long, 0.6 to 0.8 mm wide, 40 slits per metre length of pipe in 4 rows making a total inflow area of 600 mm^2 (approx.).

d). Mole drains

Mole drains (Fig. 9.1) are constructed without digging a trench by pulling a steel plug, the mole, through the subsoil at shallow depth. They are similar to pipe drains except that they are not lined. The mole drains are used to drain the heavy clay soils having low permeability. If constructed properly, the installation cost of mole drains is comparatively low but they need to be made again after a few years use. Mole drains may prove to be beneficial in Bheel soils of Cachar and clay soil of Nowgong areas of N.E. India.

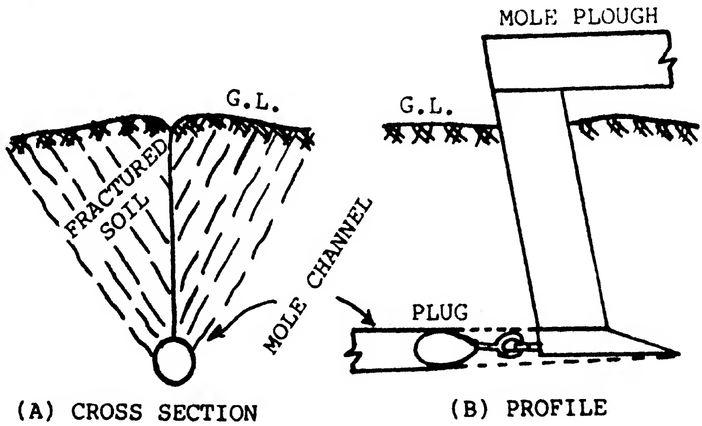

FIG. 9.1 MOLE DRAIN

Drain tile quality

Clay tiles are made of shale, fire clay or surface clay. Concrete tiles are made of portland cement.

Characteristics of good drain tile

i) resistance to weathering,
ii) resistance to chemical reaction in the soil,
iii) sufficient strength to support load under field conditions,
iv) low water absorption,
v) free from cracks and ragged ends,
vi) uniformity in wall thickness and shape.

2. Hydraulic design of pipe drain

(A) Drainage coefficient

It is the depth of water (mm) that must be removed in a 24-hour period. The factors that influence the drainage coefficient are:

(a) rainfall rate,
(b) surface runoff admitted to pipe drain,
(c) size of watershed.

(i) Steady-state situation

The drainage criteria for steady-state situation consists of a certai discharge, q, at a given ground water table midway between the drain selected according to the depth of rootzone of tea. Sometimes the thicknes of capillary fringe above the watertable is also taken intc account. The drainage coefficients estimated for different regions are given in Table 9.1

Table 9.1. Estimated values of Drainage coefficient for different regions

Zone	Drainage coefficient, mm/day
Middle and lower Assam	7-8
North Bank &	
Upper Assam	8-10
Dooars	10-15
Terai	8-10
Darjeeling	6-7
Cachar	8-10

(ii) Falling-water-table situation

In case, the design rate of drop of the water table is known, the drainage coefficient can be computed from the flowing formula:

$$DC = \frac{H}{T} \times n$$

Where:

DC = drainage coefficient, mm/day

$\frac{H}{T}$ = rate of drop of watertable, mm/day

n = drainable porosity of the soil, fraction.

(B) Drain bed grade

In order to make the pipe drain line self-cleaning, it is necessary t have a grade that will give the flowing water enough velocity to carry th sediments out of the line.

A desirable working grade is 0.20%. It is based on a minimum velocit of about 45 cm/sec at full flow. Small reversals of grade are permissibl but if the reversal is greater than 10% of the inside diameter of the pipe the discharge capacity of the drain will reduce considerably and danger o sedimentation will increase. The rate of return to established grade shall nc exceed 2% of the pipe diameter per joint of pipe. Maximum allowable departure from alignment shall not exceed 20% of the inside diameter of the pip drain with a rate of return to the established line not to exceed 5% pe

:) **Drain size**

The hydraulic capacity of the drain pipe can be determined from the]anning's formula i.e.

$$Q = DC \times A = \frac{V \times a}{100}$$

$$V = KmR^{0.667}\ s^{0.52}$$

here:

DC= drainage coefficient, m/sec

A = drainage area, m²

V = velocity of flow in the drain, cm/sec

a = cross-sectional area of the pipe drain, m²

K_m = Manning's coefficient,

K_m = 38.4 for corrugated PVC pipes.

= 51.7 for tile drains and rigid PVC pipes.

R = hydraulic radius $= \frac{a}{p} = \frac{d}{4}$

d = diameter of pipe drain, cm

s = hydraulic slope, m/m

Q = design flow rate, cum/sec

To deal with the increasing hydraulic resistance of the pipes due to ;eing, silting and poor alignment, a reduction of 25% for larger dia pipes id 20% for small dia. pipes on the drainable area is employed. After ɔmputing the required pipe diameter, the next larger commercial dia. is ;lected.

100 mm is the minimum size recommended, but 125 and 150 mm are ɔmmonly used sizes under normal conditions.

) **Drain depth and spacing**

There is a definite relationship between depth and spacing of drains. ɔr soils of uniform permeability the deeper the drains the wider the spacing 'ig. 9.2)

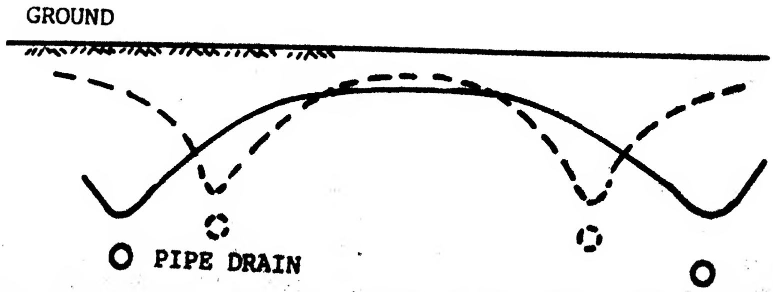

FIG. 9.2 RELATIONSHIP BETWEEN DRAIN DEPTH AND SPACING

(iii) Depth of drain

It is affected by

- Depth of outlet,
- crop requirement,
- soil type and permeability,
- drainable strata,
- drain spacing,
- depth of impervious strata,
- limitation of trenching tools.

In uniformly permeable soils (loamy sand), the depth of pipe drains can vary from 120 to 200 cm unless limited by depth of outlet.

(ii) Drain spacing

It is affected by

- depth of drain,
- hydraulic conductivity,
- amount of subsurface water to be drained,
- depth at which the water table is to be controlled.

When a single drain line is installed in the soil, the water table is lowered to the depth of the drain in the immediate vicinity of the drain and slopes upward and outward to some point horizontally where the drawdown curve becomes tangent with the original water table.

When two parallel drain lines are installed, each one exerts an influence on the water table and the two drawdown curves intersect at the midpoint between the two drain lines. By moving the two drain lines closer together, the drawdown curves intersect at a lower level at the midpoint between drain lines. This, then becomes the concept of drain spacing. Under normal conditions in tea soils (loamy sand) of N.E. India the drain spacing will vary between 30 and 50 metres for 150 cm deep drains. The drain depth is normally selected and spacing is calculated using following equation:

For steady state condition :

$$S^2 = \frac{4\,K\,H_m}{q}(2D_e + H_m)$$

For falling watertable condition :

$$\frac{K\,t}{f} = \frac{C\,S^2}{8\,D_e} \times 2.3 \log \frac{m_o(m_t + 2D_e)}{m_t\,(m_o + 2D_e)}$$

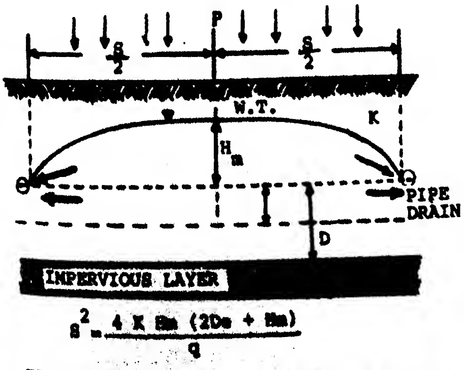

FIG. 9.3(A) DIAGRAM HOOGHOUDT'S DRAIN SPACING

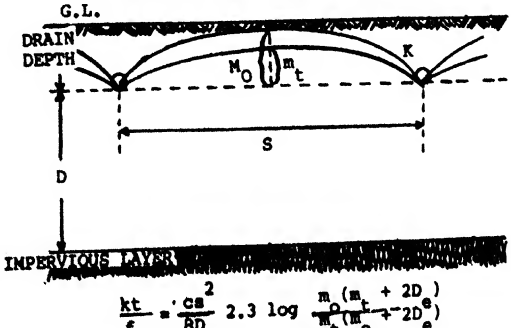

FIG. 9.3(B) DIAGRAM FOR DRAIN SPACING FORMULA FOR

here :

S = drain spacing, m
K = hydraulic conductivity, m/day
H_m = height of W.T. at midpoint between the drains, m
D_e = equivalent depth to impervious layer below drain bed level, m
q = rate of recharge, m/day
t = time for W.T. to drop from m_o to m_t, hours
f = drainable porosity (fraction)
C = a constant (0.8 to 1.0)

) **Drain filters & envelope**

Filter materials are applied to pipe drains for three purposes:

Filtering function

To prevent the entry of soil particles into the drain. It should permit e fine clay and silt particles to move through the envelope but should prent the entry of larger particles of fine sand

) **Water-conducting function**

To facilitate water flow into the drain (Fig. 9.4).

i) **For improving bedding conditions.**

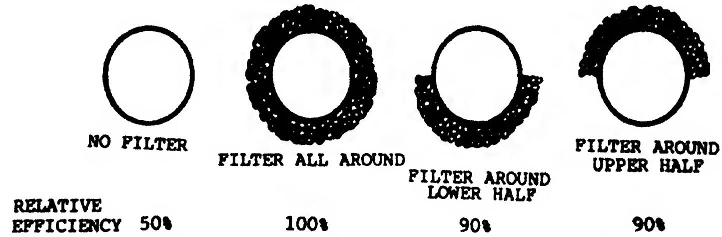

FIG. 9.4 DRAIN SURROUND TESTED BY DENNIS AND TRAFFORD (1975)

Gravel filters and envelopes are used extensively. The following equaons are used to design the filter.

Graded material :

$$\frac{D_{50}\text{Filter}}{D_{50}\text{Base}} = 12 \text{ to } 58$$

OR

$$\frac{D_{15}\text{Filter}}{D_{15}\text{Base}} = 12 \text{ to } 40$$

$$\frac{D_{50}\ \text{Filter}}{D_{50}\ \text{Base}} = 5 \text{ to } 10$$

OR

$$\frac{D_{15}\ \text{Filter}}{D_{15}\ \text{Base}} = 5$$

(F) Drain accessories

They include special facilities such as Surface inlets, Blind inlets and Sedimentation basins.

(i) Surface inlet

A surface inlet (Fig. 9.5) admits surface water into the pipe drain Whenever possible, surface runoff should be removed with shallow runof drains rather then surface inlets.

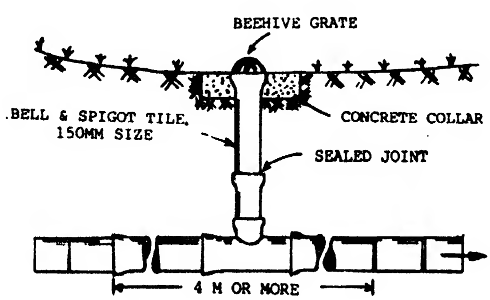

FIG. 9.5 SURFACE INLET FOR PIPE DRAINS

(ii) Blind inlet

Where the quantity of surface water to be removed is small or the amount of sediment is too great to permit surface inlets to be installed blind inlets (Fig. 9.6) may improve drainage.

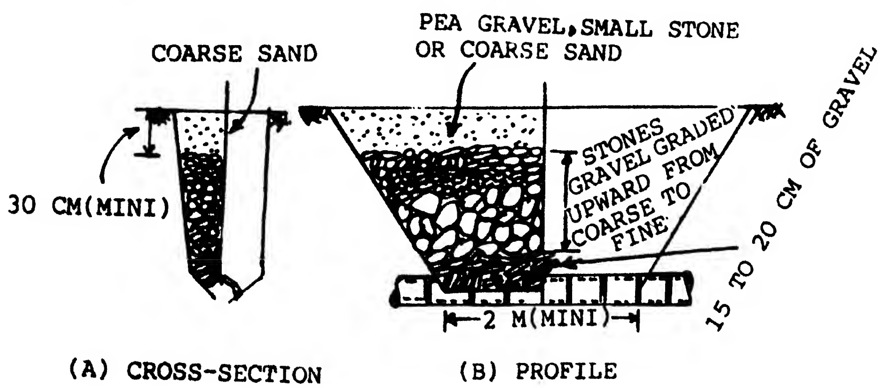

FIG. 9.6 BLIND INLET ON PIPE DRAIN

(iii) Sedimentation basin

The soils containing large quantities of fine sand cause sedimentation in the drain. A sedimentation basin is a structure that accumulates sediments and reduces deposition in the drain.

(iv) Relief pipes and breathers

Relief pipes and breathers are small size vertical risers extending from the drain line to the surface. Breathers are installed on long drain line to prevent the development of vacuum. For slopes over 1%, negative pressure could develop in a pipe drain running full. Relief pipes are used to relieve the excess water pressure in the drain during periods of high outflow, thus preventing blowouts.

3. Drain Installation

A drainage system may be adequately designed but it will not function satisfactorily unless properly installed. Drain installation includes digging to an established grade, laying the pipe, blinding and back-filling.

(i) Digging of Trench

Digging of trenches for pipe drain installation is normally done by manual labourers and hand tools. The trench can be 60 cm wide at top and 20 cm at bottom.

(ii) Drain bed grade

For hand trenching, a sight or a string-line method is commonly followed. Now laser beam equipments have also been developed.

(iii) Drain installation

Pipe drain should be laid on true grade and with good alignment and bottom support. The gap at the tile joints should be less than 3 mm in coarse-textured soils to prevent inflow of fine sand.

(iv) Blinding the drain

Blinding is accomplished by placing the designed filter material around the pipe. The minimum thickness of blinding should be 7.5 cm all around the pipe drain.

(v) Backfilling the drain (Fig. 9.7)

While digging the trench, the top soil and subsoil should be heaped separately. The excavated soil should be used to backfill the trench in the same manner as dug out to maintain original soil condition. Some extra soil should be heaped on the drain line to allow for the settlement in the trench.

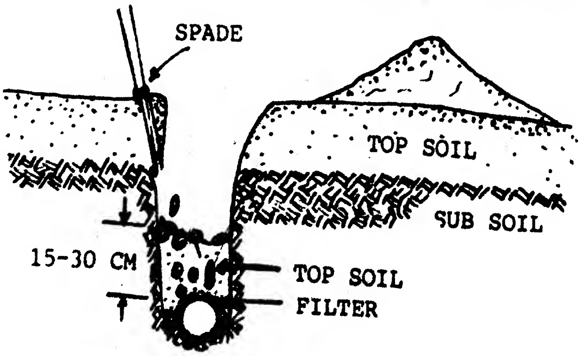

FIG. 9.7 BLINDING THE PIPE DRAIN

4. Drain maintenance

The main causes of drain failure are as follows:

(a) due to lack of inspection and timely maintenance - 29% failure,
(b) due to improper design - 28%
(c) due to improper installation - 23% failure,
(d) due to poor quality of material used - 20% failure.

Corrective maintenance

(i) Drain silting-up

Silt may be cleaned by digging holes along the line every 15 m apart. Between the holes, the silt may be removed with sewer rod. The sediments can be washed out with water forced at high pressure through a hose inserted from the outlet end.

(ii) Chemical deposits

In some cases iron-oxides and manganese oxides may be formed in pipe lines. These materials can be removed by injecting sulfur-dioxide gas for a period of 24 hours in presence of water. This problem can also be remedied by the use of 1N-H_2SO_4 and 2% sodium bisulfite solution to dissolve the oxides of iron and manganese from inside the line.

(iii) Tree roots

The roots of tea plant and/or shade tree may grow into the pipe drain. The placement of drains at greater depths will help eliminate this problem of root clogging the drain. It would be desirable to install the pipe drain in the middle of two shade tree rows. Replacing the part of the drain near an odd shade tree with blind pipe and sealing of joints will also be helpful. In the event that a drain line is plugged by roots, these can be removed with a mechanical rod made of flexible vanadium steel. Attachments can be fastened to the end of the rod to cut out the roots from the drain pipe. Soft roots of other plants may also enter the drain line but they do not cause any trouble as they die, decay and are washed away easily.

4. *Average yield*

The project area and the control plots had the same average yield per hectare before taking up the project. With time, whereas the yield of the project area having improved drainage system has increased from average 1656 kg/ha to 2134 kg/ha in 3 years period, the increase in control plot was found negligible during the same period.

Cost of drainage

The cost data have been collected from the estates where the projects were taken up. This included cost of survey, digging of drains, construction of culverts etc. and the maintenance cost of the drains. The interest on loan has been charged @ 12½% for the first year and 17% for the subsequent years as per current rate of NABARD. and commercial banks.

Yield data

The yield figures were supplied by the estates together with other details like rainfall, pruning percentage, use of inputs like fertilizers, weedicides, pesticides etc. in the project area and control plot. The present exercise is based upon the yield data only.

Contribution

The average cost of production has been taken as Rs.22.00 per kg (made tea); the fixed cost being Rs.12.00 and the variable cost Rs.10.00 per kg. The sale price is taken as Rs.25.00 per kg. Applying the formula for contribution = Average sale price - variable cost, the average contribution is estimated as Rs.15.00 per kg.

The distribution of cost on different items of drainage is given in Table 10.1.

Table 10.1 Cost of improvement of drainage system per ha for 3 years period (Rs.)

		1st yr.	2nd yr.	3rd yr.	Total
1.	Cost of survey	108	-	-	108
2.	Cost of digging drains	1752	-	-	1752
3.	Cost of construction of culverts etc.	495	-	-	495
4.	Maintenance cost	112	176	208	496
	Total (Rs)	2467	176	208	2851

The increase in yield obtained from six different drainage projects showed the trend as given in Table 10.2.

The cost distribution of improvement of drainage for the first 3 years is given in Fig. 10.1

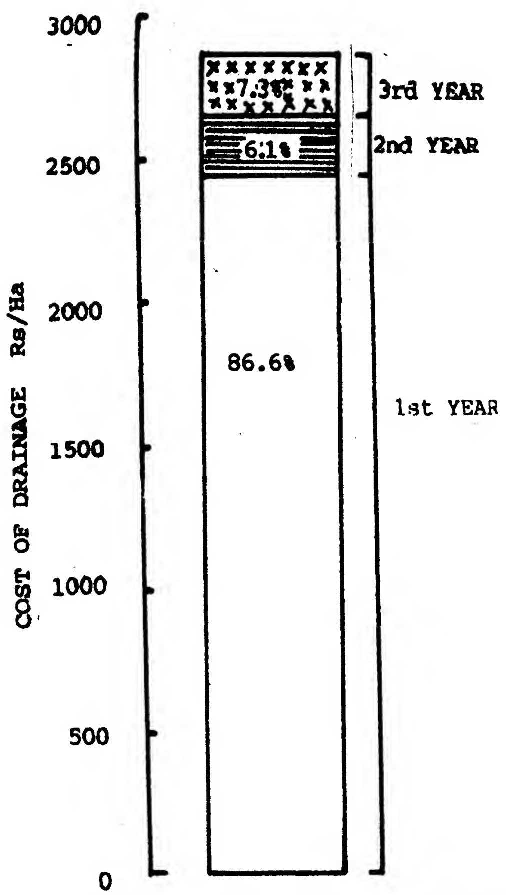

FIG. 10.1 DISTRIBUTION OF THE COST OF DRAINAGE SYSTEM DURING FIRST 3 YEARS

Table 10.2 Increase in yield from drainage projects, kg/ha

Project No.	Area (ha)	Pre-Drainage yr. yield (kg/ha)	Increase in yield, kg/ha 1st yr.	2nd yr.	3rd yr.	Total
FIRST	113	1460	364	366	555	1285
SECOND	26	2293	627	319	-	946
THIRD	48	2698	829	851	-	1680
FOURTH	138	1223	204	516	526	1246
FIFTH	555	1968	220	426	-	646
SIXTH	114	1303	265	448	478	1191
	994	1765	279	452	520	922

The total increases in yield due to improved drainage is given in Fig. 10.2.

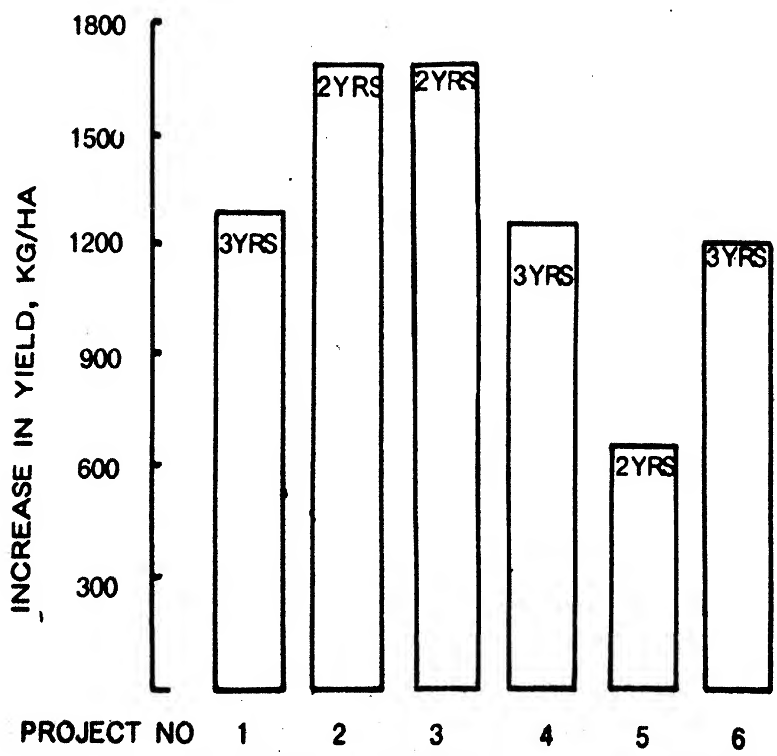

FIG.10.2 INCREASE IN YIELD AS OBSERVED IN SIX DRAINAGE PROJECTS

The average increase in yield for the six projects is taken on weight basis. The overall increase in yield in all six projects showed significant improvement.

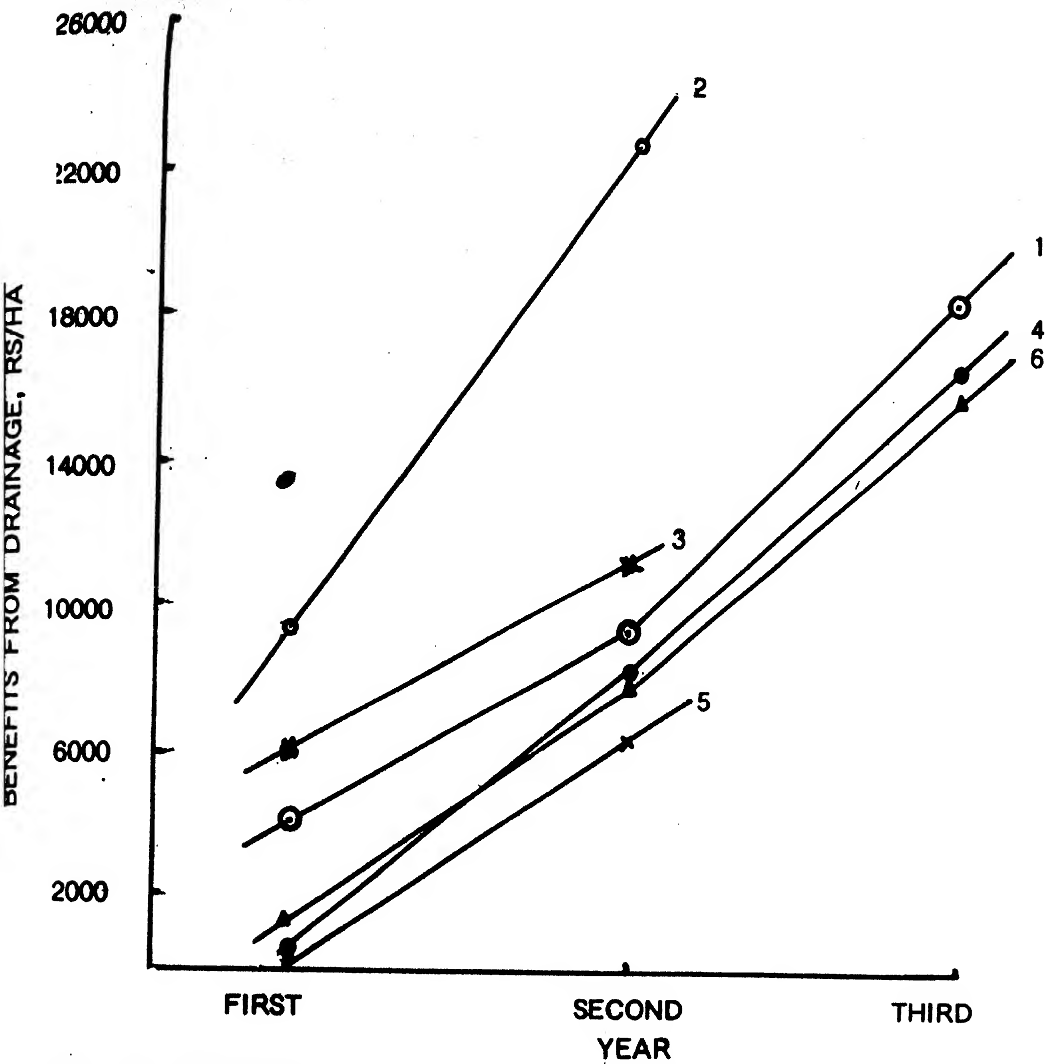

FIG. 10.3 BENEFITS FROM SIX DIFFERENT DRAINAGE PROJECTS

The details of each drainage project located in different soil and climatic conditions are discussed here. The cost and benefits very much depended on the basic factors e.g. the soil structure and agro-climatic conditions. The contribution is shown in the form of balance for each year of all six projects in Fig. 10.3.

Project No. 1 : Drainage of flat sandy loam tea soils under restricted outlet condition.

Technical details:

(a)	Project area	: 113 hectares (282 acres)
(b)	Topography	: Flat
(c)	Soil	: Deep sandy loam
(d)	Average rainfall	: 4,500 mm
(e)	Water table before drainage improvement	: 45 to 60 cm
(f)	Source of waterlogging	: Sub-surface seepage flow
(g)	Drainage outlet	: Restricted
(h)	Old drainage system	i) Lateral drains : depth=45 cm Spacing = 12m Length = 1600 m per ha ii) Sub-main drains: depth =60 cm Spacing = 50 m Length = 400 m per ha iii) Main drain : depth = 75 to 90 cm Spacing = 300 m
(i)	Improved drainage system	i) Lateral drains : depth = 105 cm Spacing = 30 m Length = 335 m per ha System = Gridiron ii) Sub-main drain : depth = 120 cm Spacing = 150 m Length = 70 m per ha iii) Main drain : depth = 150 cm Spacing = 300 m iv) Drainage pump : discharge 1.20 lal GPH at 5 m head with 12.5 HP mc
(j)	Water table after drainage	: Deeper than 100 cm

The economic evaluation of drainage improvement of Project No. 1 is presented in Table 10.3.

Table 10.3 Economic evaluation (cost benefit analysis per hectare)

Period	Cost of drainage Rs	Interest Rs	Total cost Rs	Return		Balance*(Rs
				Yield kg/ha	Contribu-tion Rs	
1st yr	1342	168	1510	364	5460	+ 3950
2nd yr.	339	58	397	366	5490	+ 9537
3rd yr.	226	38	264	555	8325	+ 18790

Cost : Benefit = 1:8.65

Project No. 2 : Drainage of Tea lands with Rolling Topography

Technical details :

(a)	Project area	:	26 hectares (65 acres)
(b)	Topography	:	Rolling
(c)	Soil	:	Loamy sand with bouldery sub-soil
(d)	Average rainfall	:	5200 mm
(e)	Water table before drainage	:	Flat ridge top 90 cm and the sloping sides - 20 to 40 cm
(g)	Old drainage system	i)	Flat ridge top; depth = 75 cm Spacing = 15 m
		ii)	Sloping sides of the ridge: No drains
(g)	Improved drainage system	i)	Flat ridge top : No deep drains required
		ii)	Sloping sides of the ridge : (a) Runoff drains; depth = 45 cm Spacing = 10 m (b) Interceptor drain : Only one across the slope, 150 cm deep at the toe of the slope. (c) System - relief drainage system with provision of erosion control structures
(h)	Water table after drainage	:	More than 90 cm

The economic evaluation of Project No. 2 is given in Table 10.4

Table 10.4 Economic evaluation (cost benefit analysis per hectare)

Period	Cost of drainage Rs	Interest Rs	Total cost Rs	Return		Balance* Rs
				Yield kg/ha	Contribution Rs	
1st yr	3056	382	3438	627	9405	+ 5967
2nd year	200	34	234	319	4785	+11264

The cost benefit ratio = 1:3.06

*Interest on balance @ 12.50%

Note : The income from interest is included

Project No. 3 : Drainage of Flat Sandy Loam tea soil having naturally hi water table

Technical details

(a) Project area	:	48 hectares (110 acres)
(b) Topography	:	Flat.
(c) Soil	:	Deep sandy loam
(d) Water table before drainage	:	40 to 60 cm
(e) Average rainfall	:	4000 mm
(f) Source of waterlogging	:	**Local rainfall**
(g) Drainage outlet	:	Partly restricted
(h) Old drainage system	i)	Lateral drains : depth = 75 cm Spacing = 50 m Length = 400 m per ha
	ii)	Sub-main drains : depth = 90 cm Spacing = 50 m Length = 400 m per ha
	iii)	Main drains : Nil
(i) Improved drainage system	i)	Lateral drains : depth = 105 cm Spacing = 30 m Length = 335 m per ha System = Grid-iron
	ii)	Sub-main drain : depth = 120 cm Spacing = 120 m Length = 85 m per ha
	iii)	Main drain : depth = 150 to 200 cm Only one main drain
(j) Water table after drainage	:	Deeper than 90 cm.

The economic evaluation of drainage Project No. 3 is given in Table10.5

Table 10.5 Economic evaluation (cost benefit analysis per hectare)

Period	Cost of drainage Rs	Interest Rs	Total cost Rs	Return Yield kg/ha	Return Contribution, Rs	Balance,* R
1st yr	2887	361	3248	829	12435	+ 9187
2nd yr	300	51	351	851	12765	+ 22749

The cost benefit ratio = 1:6.32

*Interest on balance @ 12.50%

Note : The income from interest is included

Project No. 4 : Drainage of Flat Silty-Loam soils under tea plantation

Technical details :

(a)	Project area	:	138 hectares (345 acres)
(b)	Topography	:	Flat
(c)	Soil	:	Deep silty-loam (sub-soil very dense and compacted)
(d)	Average rainfall	:	3100 mm
(3)	Water table before drainage	:	25 to 45 cm
(f)	Source of waterlogging	:	local rainfall
(g)	Drainage outlet	:	Adequate
(h)	Old drainage system	i)	Lateral drains : Depth = 45 cm Spacing = 12 m Length = 1500 m per ha
		ii)	Sub-main drains : depth = 75 cm spacing = 40 m Length = 500 cm per ha
		iii)	Main drain : depth = 100 cm
(i)	Improved drainage system	i)	Lateral drains : depth = 105 cm Spacing = 25 m Length = 400 m per ha System = Gridiron
		ii)	Sub-main drains : depth = 120 cm Spacing = 100 m Length = 200 m per ha
		iii)	Main drain : depth = 150 cm
(j)	Water table after drainage improvement	:	Deeper than 90 cm

The economic evaluation of drainage Project No. 4 is given in Table 10.6.

Table 10.6 Economic evaluation (cost benefit analysis per hectare)

Period	Cost of drainage Rs	Interest Rs	Total cost Rs	Return		Balance,* Rs
				Yield kg/ha	Contribution Rs	
1st yr.	2155	269	2424	204	3060	+ 636
2nd yr.	200	34	234	516	7740	+ 8221
3rd yr.	200	34	234	526	7890	+16905

The cost benefit ratio = 1:5.85
***Interest on balance @ 12.50%**

Note : The income from interest is included

Project No. 5 : Drainage of Flat Sandy-Loam soil under tea plantation

Technical details :

(a)	Project area	:	555 hectares (1386 acres)
(b)	Topography	:	Flat
(c)	Soil	:	Deep Sandy-loam
(d)	Average rainfall	:	4000 mm
(e)	Water table before drainage	:	45 cm
(f)	Source of waterlogging	:	Local rainfall
(g)	Drainage outlet	:	Adequate
(h)	Old drainage system		i) Lateral drains : depth = 60 cm Spacing = 7.5 m Length = 1200 m per ha ii) Sub-main drains : depth = 90 cm Spacing = 400 m Length = 500 m per ha iii) Main drains : depth = 100 cm
(i)	Improved drainage system		i) Lateral drains : depth = 105 cm Spacing = 33 m Length = 300 m per ha System = herringbone ii) Sub-main drains : depth = 120 cm Spacing = 100 m Length = 100 m per ha iii) Main drains : depth = 150 cm
(j)	Water table after drainage improvement	:	Deeper than 90 cm

The economic evaluation of drainage Project No. 5 is given in Table 10.

Table 10.7 Economic evaluation (cost benefit analysis per hectare)

Period	Cost of drainage Rs	Interest Rs	Total cost Rs	Return		Balance* Rs
				Yield kg/ha	Contribution Rs	
1st yr	2750	344	3094	220	3300	+ 206
2nd year	100	17	117	426	6390	+ 6505

The cost benefit ratio = 1:2.03
***Interest on balance @ 12.50%**

Note : The income from interest is included

Project No. 6 : Drainage of Shallow Sandy-Loam soil under tea plantation

Technical details :

(a) Project area : 114 hectares (285 acres)

(b) Topography : Flat

(c) Soil : Shallow Sandy-loam

(d) Average rainfall : 3500 mm

(e) Water table before drainage : 20 to 45 cm

(f) Source of waterlogging : Seepage and local rainfall

(g) Drainage outlet : Partly restricted

(h) Old drainage system
- i) Lateral drains : depth = 60 cm
  Spacing = 13 m
  Length = 1550 m per ha
- ii) Sub-main drains : depth = 90 cm
  Spacing = 40 m
  Length = 300 m per ha
- iii) Main drains : Nil

(i) Improved drainage system
- i) Lateral drains : depth = 105 cm
  Spacing = 30 m
  Length = 300 m per ha
  System = **Herringbone & Gridiron**
- ii) Sub-main drains : depth = 120 cm
  Spacing = 120 m
  Length = 85 m per ha
- iii) Main drains : depth = 150 cm

(j) Water table after drainage improvement : More than 90 cm

The economic evaluation of drainage Project No. 6 is presented in Table 10.8

Table 10.8 Economic evaluation (cost benefit analysis per hectare)

Period	Cost of drainage Rs	Interest Rs	Total cost Rs	Return		Balance* Rs
				Yield kg/ha	Contribution Rs	
1st yr	2355	294	2649	265	3975	+ 1326
2nd yr.	200	34	234	448	6720	+ 7978
3rd yr.	200	34	234	478	7170	+15911

The cost benefit ratio = 1:5.10
*Interest on balance @ 12.50%

Note : The income from interest is included in Column 7.

The economic evaluation of six different projects indicated the vari tions in cost due to difference in soil structure and rainfall pattern et Accordingly the benefits from improved drainage also varied.

The additional benefits due to better utilization of inputs like fertil zers and reduced expenses on control of weeds and pests have not bee taken into account here for estimating total benefits. It is quite obvious the improved drainage will play a significant role in increasing the yield c mature tea areas in N.E. India. In addition, the adoption of scientific drai nage system in the extension and replanted areas in future will also give major boost to the productivity of young tea areas of N.E. India.

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DRAINAGE IN TEA
1993

A Compilation of lecture notes

Edited by

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FOR TRA MEMBERS ONLY

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IMPORTANCE OF DRAINAGE IN TEA

J.Chakravartee

Considering the recent scenario of Indian tea production, the industry will have to set in gear effectively all its production inputs towards achieving the targeted production by the turn of the century. Drainage has been recognised as one of the major inputs by various expert bodies/committees set up by the Government. Efficiency of different inputs increases only when the tea plants are grown in a well drained condition.

It is estimated that India will require around 1000 million kg of made tea by the turn of the century in view of the fast increasing domestic demand and to retain its share of the world tea market in the coming years. Since North East India produces around 75 per cent of the total tea in the country, its share of production comes to 750 million kg by 2000 A.D. It is therefore, apparent that unless the production targets are consistently and systemetically persued, it is bound to jeopardise both the domestic intake and the vital export profiles.

It is roughly estimated that over 2,00,000 hectare of tea lands suffer from waterlogging and require scientific drainage system. In addition, about 50,000 hectares of marginal/sub-marginal land available with tea gardens can be reclaimed for tea plantation through scientific drainage and soil management techniques.

Drainage in tea deals with disposal of surface and sub-surface water. The objective of surface drainage is to remove excess water from the surface of land through land grading, construction of ditches and improving natural channels, and to control of valuable top soil loss by erosion. Sub-surface drainage is for removal of excess gravitational water from the root zone to attain equilibrium of soil-air-water status required for plant growth. For an effective and ecnomic drainage improvement, good outlet is a prime necessity.

Our problem starts here. The Brahmaputra and the Barak river dominates the valley forming the tea growing areas of the north eastern India. The region receives heavy downpour due to South West monsoon in four months (July to October) which is about 60 per cent of total annual rainfall. Several severe earthquakes shook the region in the recent past causing heavy land slides. These sediments were carried by the river and deposited on the river bed downslope. Rapid unplanned and indiscriminated deforestation also took place in the upper catchment and increased the sediment load of the river. Reduction of forest covers made the flood flashy. Flashy flood caused erosion of river banks. Due to siltation of river bed the drainage base was gradually rising which induced waterlogging of fresh areas year by year. The figure below bears the testimoney of how river beds aggravating with time (Fig.1).

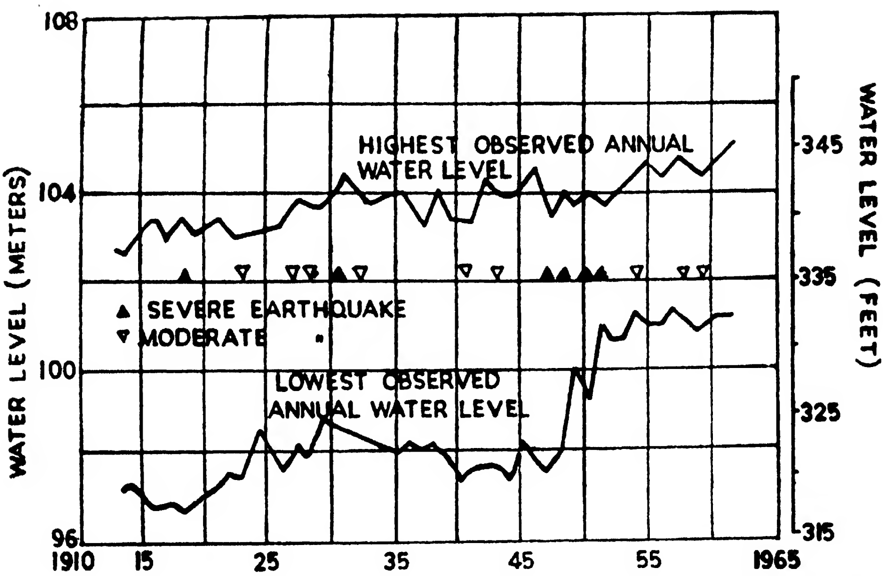


Fig.1. Brahmaputra water levels at Dibrugarh (From IND.J.of Irrigation and Power, January 1964, paper by G.M.Panchang).

Root development of a tea bush is connected with drainage condition. If drainage is inadequate and water table remains high during the growing period, the tea bush developes a shallow root system and in servere cases even starts decaying of the roots. Assured drainage to maintain water table at a minimum depth of 100 cm is the basic need for growing tea. Various factors including flood often hamper drainage. Some of such factors are:

(1) Culverts and bridges of inadequate size both inside and outside tea estates including those provided on the national highways and railway lines.

(2) Heavy siltation of natural water ways or, blockage of natural water ways which otherwise would have served as outlets.

(3) Unplanned roads, bunds and even straight roads and drains inside the estate to obtain regular shaped fields (Sections) without considering the topography.

Soil is one of the basic resources on which all plants and animal life depends. Although man's use of land can often have damaging effects on the soil, such effects can be minimised by careful handling of the basic resources (i.e. soil,water and vegetation). This is called planning.

Planning with futuristic approach is essential in tea cultivation which is a perennial crop. Whatever we do we have to do for our benefit and survival. Unless our actions are based on conservation, much developments will continue to have unacceptably harmfull side effects, provide reduced benefits or, even fail altogether. Normally tea estates are diveded into sections on an arbitrary basis. Boundaries between estates are again arbitrary. Straight lines are drawn across the map and demarketed on the land by straight drain or vacant strip of land. All these straight roads and drains, regular shaped fields, straight tea rows are against the principle of conservation and often cause problems in planning drainage net work in the tea estate.

Besides these there are problems of different nature associated with waterlogging in tea fields.They are:

(i) Restricted outfall

(ii) Seepage from upper catchment

(iii) Run-off from upper catchment

(iv) Drain side collapses

(v) Sand boiling

(vi) Smaller drain size

(vii) Wrong placement of culverts.

(viii) Weed growth on the drain beds

(ix) Ponding due to uneven land surface

(x) Sub-soil impermeability.

(xi) Artesian spring.

These problems will be adequately dealt with during the next four days.

As a factor limiting plant growth over the land surface of the earth, water probably is foremost in importance. We all know that the distribution of rainfall in N.E. India is uneven. The monts of November to March are normally dry and the period from May to October is very wet. In addition , there is a problem of receving about 60 per cent of the total rainfall at intensities of sufficient magnitude that can cause erosion. Added to this, rise of underground water into the root zone or even higher (say 30-40 cm of soil surface) in low laying areas also cause immense problem to tea plant causing gradual decline in yield.

Waterlogged plants exhibit prominent symptoms which should be taken as a guideline for investigating the causes of waterlogging and also for finding out solutions. These symptoms are:

1. Scanty shoot production.

2. Yellowing of leaves and premature defoliation.

3. Dieback of plucking points and poor recovery from prunning.

4.Infection by violet root rot and red rust diseases.

5. Shallow root system and more severe drought damage in the cold weather.

6. Loss of vigour and finally death of plants.

Waterlogging problems of various nature were identified in the tea growing areas of N.E. India and these are:

(1) Blockade of natural outlets owing to unplanned land use leading to erosion and siltation—These could also be due to urbanization and unplanned actions of the field management practices in agricultural field. Seen in Makum, Dibrugarh, Sibsager and Nagaon areas.

(2) Land locked conditions-No natural drainage base is available nearby. Seen in Jorhat, Sibsagar, Dibrugarh areas.

(3) Sand boiling-caused by pressure exerted by seepage water on light textured soil. This causes the canal bed to rise and create a sand boiling situtation. This was noticed in an estate near Amguri.

(4) Man made obstruction of natural water ways-Normally associated with industrialization. Seen in an estate near Lukwah.

(5) Coarse textured soil in the lower layer of soil profile-causing unstable drain condition and subsequent restricted flow.

All these problems with possible solutions will be discussed during the next four days.

HYDROLOGY OF MICRO-CATCHMENT

P.K. BORDOLOI

The design of an agricultural drainage system requires a good understanding of the occurance and nature of movement of water in the soil as well as of surface runoff. The science that deals with distribution of water on the earth, beneath the surface and in the atmosphere, in different form, is called Hydrology.

1.1.**The Hydrological Cycle:** In this lecture we will discuss the portion of Hydrology that is relevant to drainage in tea. Atmospheric moisture travel towards the earth surface, in north east India in the form of rain and sometimes hail. The portion of water reaching the ground may follow several paths, some will evaporate back into the atmosphere, some will infiltrate in to the earth. If rainfall intensity exceeds the combined infiltration and evaporation rates, puddles will form. Water retained in puddles is said to be in depression storage.

As the puddles fill and overflow, water begins to move across the surface, along the depression, towards the drainage base. This drainage base may be a drain, a hullah, a stream or a river. This water is called surface runoff.

The water that infiltrates into the ground, first enters root zone of the soil. This water may return to the atmosphere through evaporation from the soil surface and transpiration through the plants. Soil layers can hold water upto field capacity of the soil under balanced condition. If water is added to soil zones beyond field capacity it fills up the macropores present in the soil and passes to a lower zone called saturation zone or ground water zone by percolation. Water leaves the groundwater zone by capillary action in to root zone and by seepage into streams.

1.2 **Source of water in micro-catchment: Let us seperate the surface and subsurface water of the hydrologic cycle as follows (Fig. 1 and 2):**

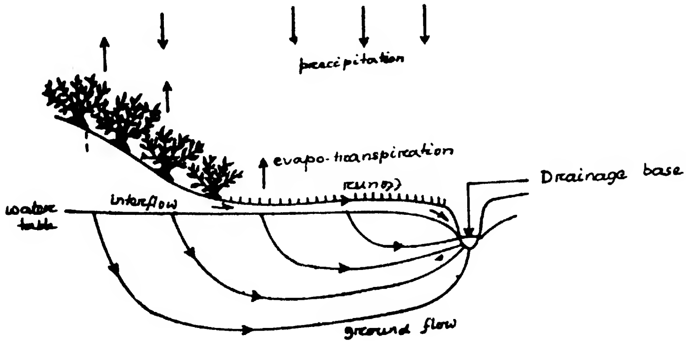


Fig. 1

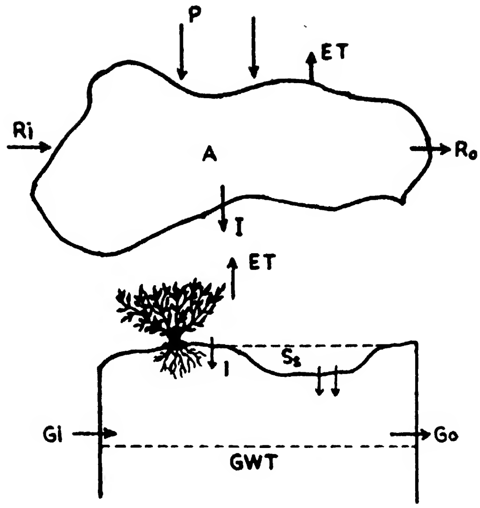


Fig.2

(P-ET+Ri-Ro-I) A = Surface storage (Ss) (1)
(I+Gi-Go) A = Ground storage (Sg) (2)

Where,
P= rainfall
Ri= Runoff from upper catchment
Ro = Runoff at outlet,
I = Infiltration
ET= Evapo-transpiration

A = Drainage area

Go = Seepage from the catchment

Gi = Seepage from upper catchment

Adding both the equations

A [P + (Ri-Ro) + (Gi-Go)—ET] = Total Storage (S)

Increase in the total storage leads to water logging. Therefore, for a good drainage, water management system should be able to reduce this storage. Out of these parameters, precipitation cannot be controlled. Runoff inlet (Ri) can be controlled/stopped by constructing embankment encircling the periphery of the estate. Subject to outlet condition, properly graded channel can increase the discharge rate (Ro) by gravity or by pumping. Seepage from upper catchment (Gi) can be diverted by interceptor drains or by constructing physical barriers. Field drains of suitable depth and spacing or pipe drains can increase the rate of seepage outflow (Go) from the catchment. If the area (A) is bigger one, then it can be divided in to small subcatchments so that the total storage is reduced. Then the equation becomes

$$A. (P-ET-Ro-Go)= S \qquad (4)$$

1.3. Surface slopes: The combined effects of surface flow, groundflow shed rainfall off the slope and cause water to be accumulated in valleys and hollows. Groundflow often caused continued accumulation of water in collecting sites after the rainfall has stopped. It has a significant effect on the groundwater table which is also confirmed during various field trials conducted by Tocklai. Thus the general level of the ground water table is determined by the topography of the areas. Therefore, topography governs both surface and subsuface flow. The topographic features can be determined by level surveying.

1.4. Investigation of surface and sub-surface drainage:

1.4.1. Surface Drainage: For planning and designing of drainage projects following data are to be collected-

(1) Topographic survey

(2) Soil survey-physical properties

(3) Rainfall

(4) Average and high flood level of drainage outlet

(5) Profiles and cross-section of existing drain

(6) Drain stability

(7) Cross-drainage works.

1.4.2. Sub-surface drainage: Informations of soil, sub-soil, ground-water table are needed to be collected in the following manner:

(1) logs of sub-soil,

(2) hydraulic conductivity

(3) level of groundwater table and its fluctuations.

1.5. Types of drainage problem

The most typical drainage problems faced by the tea industry are restricted outlet, higher ground water table , seepage water , artesian flow and safe disposal of water from sloppy land.

Out of these, disposal of excess water surface and sub-surface, surface disposal is easier and can be managed. But disposal of sub-surface water is problematic as the flow of subsoil water is influenced by physical properties of soil. By keeping the drain water level low, potential of movement of ground water can be increased but rate of flow is govern by hydraulic conductivity of the soil.

Since ground water movement is very slow, therefore, efforts should be made to reduce the load of excess soil moisture. Higher water level in the drains cause reduction in potential difference, which in turn, will retard the flow of ground water. It causes the root zone to submerge leading to water logging. Seepage from upland helps in building up of water table, as well as by the deep percolation of puddled water. Efforts should be made to reduce the effects of the agents causing water logging of the root zone.

Restriction of outlet, will cause drain water to build up and even at times can inundate the tea areas. In such areas development of artificial outfall will be necessary. Runoff from higher catchment can be prevented from entering to tea areas by constructing physical barriers-like earthen dike or bund. The seepage flow can be stopped by means of cut off contour drain at the base of the slope and along the periphery of the estate. To reduce puddling, land grading before planting and filling up the uneven surface in case of established tea, should be undertaken.

1.6. Aim of drainage: The aim of the drainage planning is to remove the excess moisture in the root zone, as early as possible, so that the soil returned to field capacity without doing any harm to the bushes. Therefore, quick and safe disposal of water from the catchment forms the basis of the drainage design.

The basic hydrologic equation is, rate of inflow-rate of outflow = rate of change of storage. Building of storage leads to waterlogging. The measures to be taken to reduce the inflow is already discussed. By augmenting the outflow rate waterlogging can be reduced preve-nted. To augment the outflow-development of outlet should be given the top priority. Without a proper outlet, drainage planing cannot be successful. Hence for an efficient drainage layout development of outlet should be taken up first. Therefore, the principle of planninng of drainage system is from 'whole to part' aiming at lowering of watertable below root zone depth without doing any harm to the bushes.

IMPORTANCE OF TOPOGRAPHIC SURVEY IN PROPER LAND USE AND DRAINAGE PLANNING

N. BORPUJARI

INTRODUCTION

Soil is one of the basic resources on which all plant and animal life depends. It possibly takes millions of years for the nature to produce a foot depth of top soil, but unplanned land use by man can destroy it within a couple of years. Loss of soil by way of erosion is the major concern of modern agriculture and tea is no exception. With proper land planning and conservation measures we can use the soil to our advantage to sustain productivity in perpetuity.

Soils have limitations and differ in their capability to support and sustain plant growth. Based on kind and degree of limitations, soils are classified into various land capability classes shown hereunder. Such land classification is applicable to tea areas also so that decisions on diversification, replanting, management and conservation needs existing tea areas can be taken.

CLASS I: Very good land in all respect and can be cultivated safely with minium conservation measures.

II: These are also good land having crosion hazards.

III: Moderately good land needs special soil conservation measures.

IV: Moderately good land with serious erosional hazards.

V: Swampy, stony and old river course, unsuitable for cultivation.

VI: Land with steep slope, subject to severe soil erosion. Suitable for grazing and forestry purposes.

VII: Steep slope, having severe erosional hazards, suited only for grazing, forestry and plantation crops.

VIII: Land is of no agricultural use

Several kinds of limitations such as slope, soil depth, texture, high water table, problem of safe disposal of water, permeability etc. can exist in tea soils. However, for management of tea soils, a more simplified or modified classification can be adopted based on the current knowledge and understanding of the factors that influence the growth of tea.

For classification of tea soils factors like texture, and soil depth, permeability, slope, transitional and mottled layer, out fall are taken into consideration and based on these factors, areas in a tea estate can be classified for adopting the best soil, water and bush management practices. An example of such a classification is given below :

CLASS I: Land subject to few limitations, such as not prone to erosion, adequate soil depth and easily drainable. Only limitation of maintenance of soil fertility.
-- Generally high flat lands and or with mild undulations.

II: Land subject to moderate limitations, e.g. not prone to erosion, moderately permeable sub-soil layer, but limitations on maintenance of soil structure, fertility and sub-soil drainage.
-- Generally flat lands with heavy soil texture.

IIB: Similar limitations as above but main limitations imposed by high water table, deterioration of soil structure, needs intensive measure for improvement of land drainage.
-- Generally flat lands of low elevation.

III: Land subject to severe limitations such as high susceptibility to erosion. A combination of intensive drainage and mechanical soil conservation measure are needed for permanent land use.
-- Generally undulating and hilly lands.

Studies carried out in the past indicated that majority of the land under tea have limitations imposed by sub-soil drainage, maintenance of soil structure, soil fertility and moderate to severe susceptibility to soil erosion. These lands, therefore, can remain under tea for a long period provided it is properly drained, fertility is maintained and adequate care is taken to preserve the top layer of the productive soil.

LAND USE PLANNING

In a tea estate for formulating a proper land use Master Plan, the following are essential :

1. A layout map of the tea estate where roads, paths, sectional boundaries, buildings, natural waterways, bridges, culverts etc. are clearly marked.

2. A topographical map of the tea estate for delineating the watersheds, major and minor catchments for planning and land use.

Appropriate survey is, therefore, necessary to prepare the document for finalising the land use and drainage plan.

LAND SURVEYING

1. For Area determination :

(i) **Chain Triangulation or Chain Survey**

In this method of surveying, the surveyed area is divided into triangles in the field and the area is computed from the sides of the various triangles. All the internal details are filled in during the survey and on the basis of the information, a detailed lay out plan map of the estate is prepared.

(ii) **Plane Table Survey**

Plane table survey is a graphical method of survey where the field work and the plotting are done simultaneously in the field. All the internal details are filled in during the survey work and the map is drawn as the survey work proceeds. This method is best suited for open country where obstacles are few.

2. For Topography determination :

Level Surveying

For topographical planning, level surveying is used. In this method the relative heights or the difference in elevation of various points on earth's surface is measured and a topographical map is prepared.

In level surveying the following terms are commonly used:

<u>Level line or Level plane</u>

The example of a level plane is best typified by the water surface of a still lake where the curvature of the earth's surface is clearly exhibited (Fig.1).

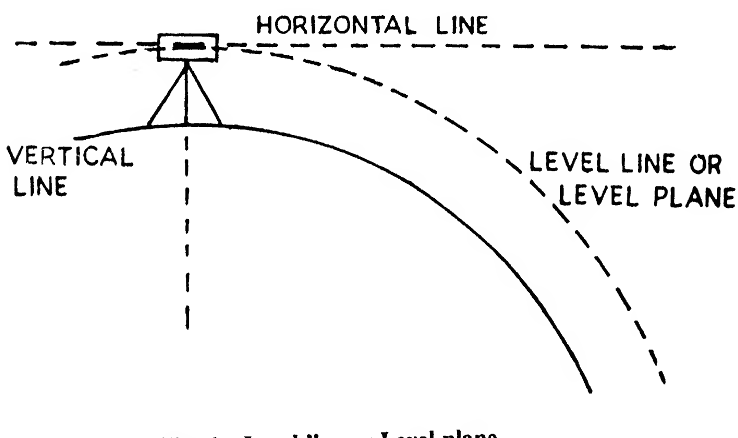


Fig. 1. Level line or Level plane

Horizontal Lines

A horizontal line runs tangential to the level line or plane.

Datum line or surface

From a datum line or surface the elevations or vertical distances are measured. The elevation of a datum line or surface is arbitrarily assumed.

Reduced level (R.L.)

The points of relative elevations or depressions on earth's surface with respect to the datum line or surface is known as the Reduced level.

Bench mark

Field reference points of known or assumed elevation is called Bench marks.

Line of collimation

This is an imaginary line which connects the cross hair and the eyepiece of the levelling instrument with the object in a straight line. (Fig.2)

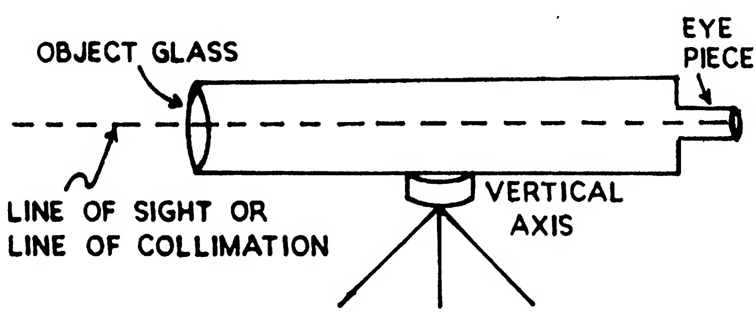


Fig. 2. Line of collimation

Vertical axis

This is the centre line of rotation of the instrument.

Back sight (BS)

The first staff reading taken on a bench mark is called a Back sight.

Fore sight (FS)

Fore sight is the last staff reading taken on a point whose elevation is to be determined before shifting the instrument to a new position.

Intermediate sight (IS)

All the staff reading taken on points between Back sights and Fore sights are known as Intermediate sights.

Change points (CP)

During the course of survey the levelling instruments is shifted to new places for convenience which are called the Change points. (Fig.3)

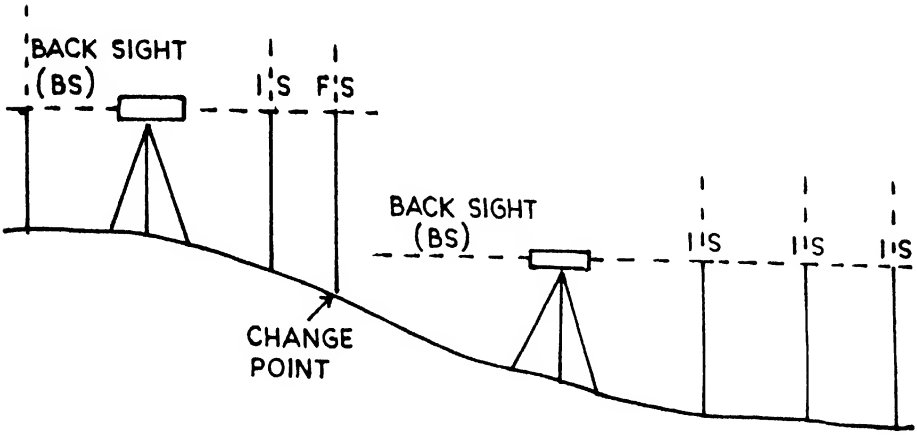


Fig. 3. Change points (CP)

Height of instrument (HI)

The elevation of the line of collimation, when the levelling instrument is correctly levelled, is called the Height of instrument.

LEVELLING INSTRUMENT AND EQUIPMENTS

Dumpy level

It is a simple, compact and stable levelling instrument commonly used for level surveying. The telescope is rigidly mounted to its supports and therefore, it can neither be rotated about its longitudinal axis not can be removed from its supports. (Fig.4)

Levelling staff

These are wooden graduated staff normally 5 m long when fully extended and used for taking reading by a dumpy level. The staff is graduated in metre, tenths and two hundredths and the figures are painted in different colours. The metre figures are painted in red on the left, the odd tenths of the metre in black on the right and the two hundredths are indicated by alternate white and black spaces on the levelling staff.

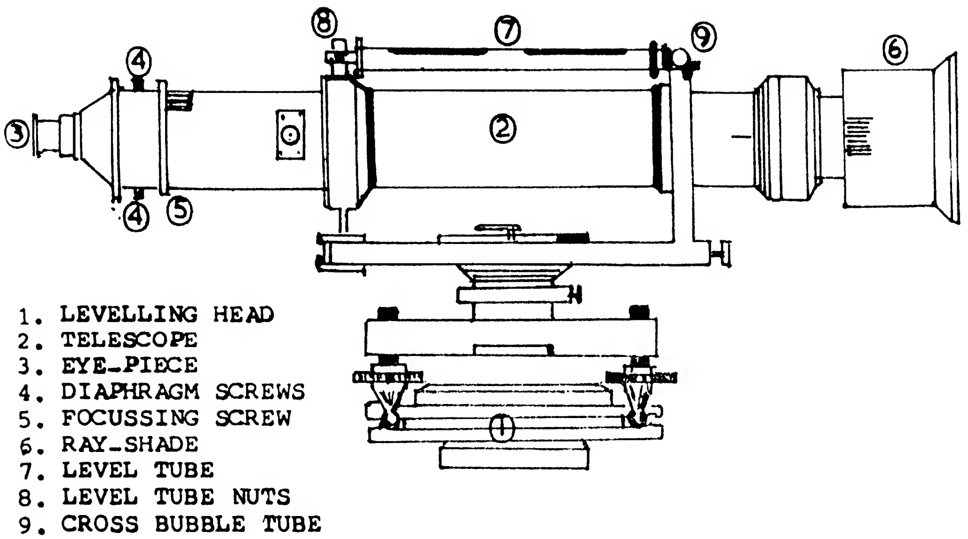


Fig. 4. Dumpy level.

Chain or tape

Steel chains or tape aré required for measuring horizontal distances. The chain can be either Gunter's chain or Engineer's chain with different links lengths.

Level field book

For recording the staff readings, stations, distances and other details, field books are necessary in level surveying.

Bamboo stakes

Sufficient numbers of bamboo stakes are necessary for marking the survey points on the ground.

PROCEDURE OF LEVEL SURVEYING

1. Preliminary works

Before commencement of surveying,the scale of the map should be decided as follows:

Scale	Area	Spacing of grid point
40 cm to 1584 m	240 ha(600 ac) or more	50 - 60m apart
80 cm to 1584 m	120 ha(300 ac) to 240 ha (600 ac)	30 - 40m apart
160 cm to 1584 m	Less than 120 ha (300 ac)	10 - 20m apart

Having selected the site and the scale of map for level survey, the area should be surveyed with the help of either Chain and compass or by Plane table and accurately measured. The area is then divided into equal grids and each grid point is marked on the ground by driving numbered bamboo stakes on each point. These grid points should tally accurately with map of the area drawn on the survey sheet.

Staff readings with the help of a dumpy level are taken on each grid point and the reduced level of each point is then calculated. On the basis of these figures, contours are drawn on the map later in the office. While dividing the area into grids, it should be remembered that on slopy areas the grids should be closer and on flat land these can be spaced out accordingly. (Fig.5)

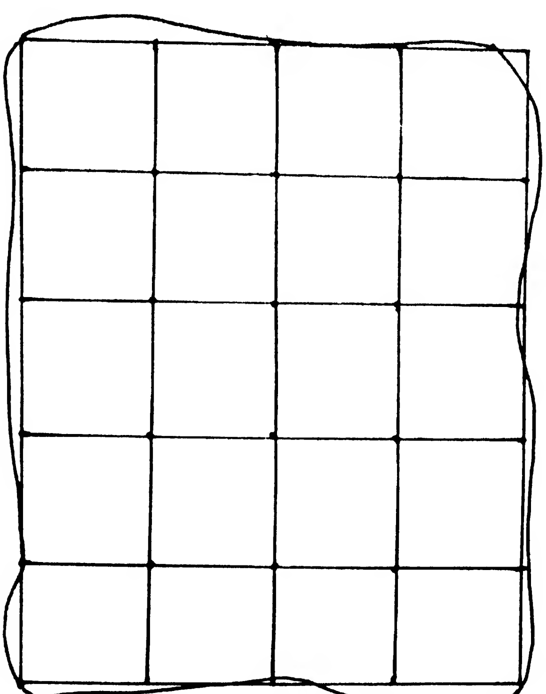


Fig. 5. Area is divided into equal grids

2. **Setting up of the Dumpy level**

a) **Fixing the instrument on the tripod.**

After releasing the clamp screw, hold the instrument firmly and fix it on the tripod by rotating the lower part to screw the instrument properly in the grooves.

b) **Focussing the eye-piece**

Remove the cover from the end of the object glass of the telescope and hold a piece of white paper in front of it. Now move the eye-piece in and out until the cross hairs are clearly seen.

c) **Leg adjustment**

Place the instrument in a desired position at a convenient height for sighting by spreading the legs well apart. Bring the levelling screws in the centre of their run. Fix firmly any two legs on the ground by pressing with hand and move the remaining leg right or left until the main bubble on the telescope comes to centre.

d) **Focussing the object glass**

Aim the telescope on the staff and by looking through the eye-piece bring the image on the staff between the two verti cal hairs of the diaphragm by lightly tapping the telescope. Now adjust the object by turning the focussing screw to eliminate the parallax.

e) **Levelling up of the instrument**

Bring the telescope parallel to a pair of foot screws and turn these screws either inward or outward to bring the bubble to centre. Turn the telescope to its original position without reversing the position of the eye-piece and the object glass end. Turn the foot screws again inward or outward until the bubble comes to centre of its run. Repeat the operation again and again until the bubble remains in the centre of its run in both the positions. If the instrument is correctly levelled then the bubble will remain in the centre for all directions of the telescope.

f) **Reading the staff**

For reading the staff, it should be positioned on the station vertically. The man holding the staff stands behind it, positions the heel of the staff between his toes and holds the staff between his palms at the height of his face.

While taking staff reading, bring the figure on the staff between the two vertical hairs of the instrument and use the portion of the horizontal cross hair where it cuts the figure. First note the red figure then the black figure and finally count the spaces for recording the reading.

The principle on which the method of levelling is based is shown below (Fig.6) :

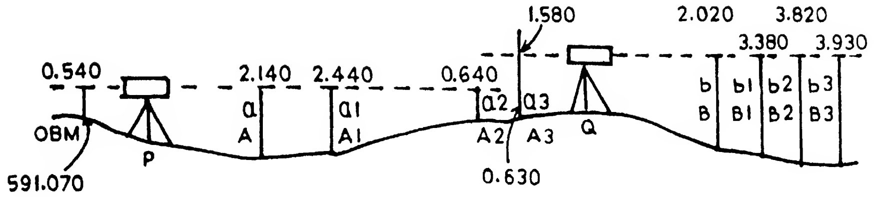


Fig. 6. Principle method of levelling

The dumpy level is set up at a convenient position say at point P and Back sight taken on a Bench mark. It is placed in such a way so that the staff readings at A, A1, A3 and so on can be taken whose levels are to be determined. The horizontal distance between the stations are measured with the help of tape or chain on the ground.

The straight line a1, a2, a3 etc. is the line of collimation of the instrument. The staff readings at points A, A1 etc. are the vertical distances of the points whose levels below the line of collimation are required. The staff reading of these points are then recorded on a field book. On reaching point A3, the instrument is shifted to the new position Q and the line b, b1, b2 etc. represent the new line of collimation and the reading of the staff continues from the new position.

SYSTEM OF BOOKING LEVELS

The following systems are used for booking a series of staff readings on a level book :

i) The Height of Instrument or Height of Collimation system

ii) The rise and Fall system

Height of Instrument system

In this system the plane of collimation is found out for every set up of the instrument and the reduced levels of all the points with reference to the respective plane of collimation are calculated.

The following table shows a page from a level book for Height of instrument system of booking. The staff readings from the above figures are used to fill in the columns and the reduced levels are calculated as follows (Table 1) :

(Table 1)

Station	Distance in metre	Back sight	Inter-mediate sight	Fore sight	Height of Instru-ment	Reduced level	Remarks
		0.540			591.610	591.070	ON OBM 591.070
A	0		2.140			589.470	
A1	10		2.440			589.170	
A2	20		0.640			590.970	
A3	30	1.580		0.630	592.560	590.980	(CP)
B	40		2.020			590.540	
B1	50		3.380			589.180	
B3	70			3.930		588.630	
		2.120		4.560		591.070 -	588.680
Checks:		4.560 -	2.120 =	2.440	=	2.440	

After levelling the instrument, the first staff reading 0.540 taken on OBM (Observed Bench Mark) 591.070 is always entered as Back Sight (BS) and all the subsequent readings, except the last, for any particular set up are entered as Intermediate Sights (IS). The last staff reading either at the Change Point (CP) or at the end of days work is entered as Fore Sight (FS). The staff reading at OBM 0.540 is then added to the OBM of 591.070 to calculate the Height of Instrument which is 591.610. All the subsequent readings on points A, A1, A2, A3 etc. are Intermediate Sights. Before moving the instrument to a new position, the last staff reading taken on that point will be Fore Sight (FS). The Reduced Levels of these points are calculated by substracting the staff readings of all these points from the Height of Instrument.

The instrument is then moved to a new position (CP) Q while the staff is still being held at A3. As explained earlier, before moving the instrument, the last staff reading is taken at point A3 will be recorded as Fore Sight (FS). After setting up the instrument at Q the first staff reading taken at A is called the Back Sight (BS) and here it is required to calculate a new Height of Instrument for the present set up. This is calculated by adding the Back Sight on A3 (1.580) to the Reduced Level of A3 (590.980) i.e. 592.560 and thereafter the Reduced Levels of all the subsequent points are calculated by substracting the staff readings from the new Height of Instrument.

The results thus obtained needs to be checked by adding up all the Back Sights (BS) and Fore Sights (FS) separately and substracting the lesser of the sums from

the greater. The difference obtained should be same as the difference of the first and the last Reduced Levels. In the above example, this is calculated as follows :

SUM OF FORE SIGHTS	=	4.560
SUM OF BACK SIGHTS	=	2.120
Difference	=	2.440
FIRST REDUCED LEVEL	=	591.070
LAST REDUCED LEVEL	=	588.630
Difference	=	2.440

Therefore, both the differences are equal and the survey work is correct

Rise and Fall System

In this system, in the level book, instead of Height of Instrument column, rise and fall columns are given. The following table is representing a page of level book under rise and fall system (Table 2) :

(Table 2)

Stn.	Dist in (m)	Back sight	Interme-diate sight	Fore sight	Rise (+)	Fall (-)	Reduced level in metre	Remark
		0.540					591.70	OBM = 591.070
A	0		2.140			1.600	589.470	
A1	10		2.440			0.300	589.170	
A2	20		0.640		1.800		590.970	
A3	30	1.580		0.630	0.010		590.980	(CP) Change point
B	40		2.020			0.440	590.540	
B1	50		3.380			1.360	589.180	
B2	60		3.820			0.440	5888.740	
B3	70			3.930		0.110	588.630	
		2.120		4.560	1.810	4.250	591.070 -	588.630

Checks: Sum of FS - Sum of BS = 2.440
Sum of Rise - Sum of fall = 2.440
First RL - Last Rl = 2.440

The first staff reading (BS) on OBM 0.540 is substracted from the Intermediate sight on point A 2.140 and the result is booked in column Fall as the first staff reading on OBM is higher than the second staff reading on point A. This process continues down the page, each staff reading is substracted from the one next below and if this reading is bigger than the previous one, the difference will be booked in Fall column and if the difference is smaller then it will come under Rise column.

The Reduced Levels are found by adding successively all Rises and substracting all Falls from the previous Reduced Level.

ERRORS IN LEVELLING

Instrument

The instrument should be in perfect adjustment and the line of collimation must be parallel to the bubble line. Both of them must be at right angle to the vertical axis.

Errors in manipulation

While taking Back Sight or Fore Sight, if the bubble is moves out of centre, then it should be brought to the centre by turning the screw(s) which are nearest in the line with the axis of the telescope. Once the adjustment is done do not touch the legs of the Dumpy level. The error increases with the increase in the staff reading and is maximum when the reading approaches the top.

Errors due to settlement of level or staff

If either the legs of the instrument or the staff settles down on soft ground, the bubble gets disturbed. Therefore, both the level and the staff should be placed on firm ground.

Errors in sighting

The common error is due to parallax. Therefore, the eye-piece should be focussed properly to eliminate this problem.

Bubble correction

If the bubble moves out of the central position, bring the telescope parallel to the first pairs of the foot screws just to see whether it returns to the centre. Then the telescope to far end and note its departure from one half of its departure i.e. n divisions by turning the capstan-headed nut at one end of the tube which connects the bubble tube to the telescope and the other half by turning the foot screws and bring the bubble to the centre. It may require one or more trials to do this.

THE INTERPRETATION OF CONTOUR LINES

Contour lines are drawn on the survey sheet by joining the points of equal heights (Reduced Level). The specimen of a level survey map showing the reduced levels of grid points and the contours is given below:

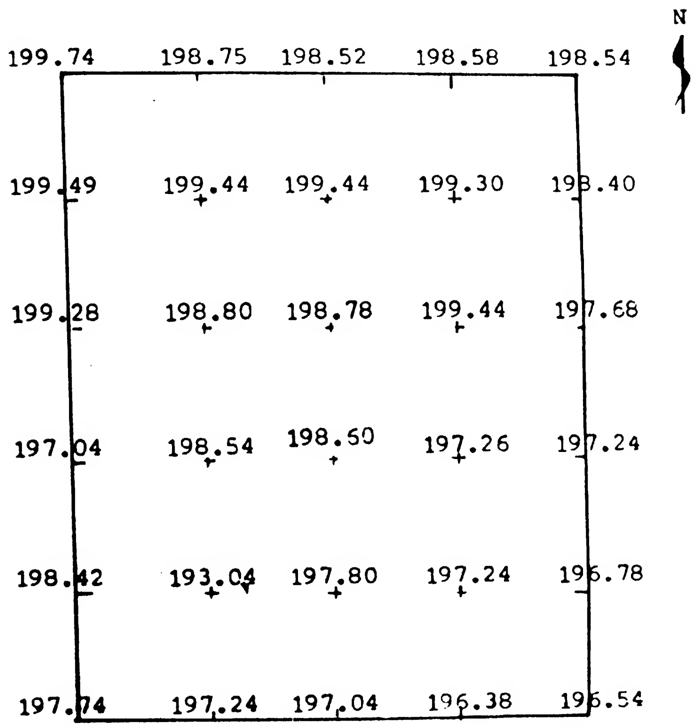


Fig. 7A. Grid Points and Contour Lines

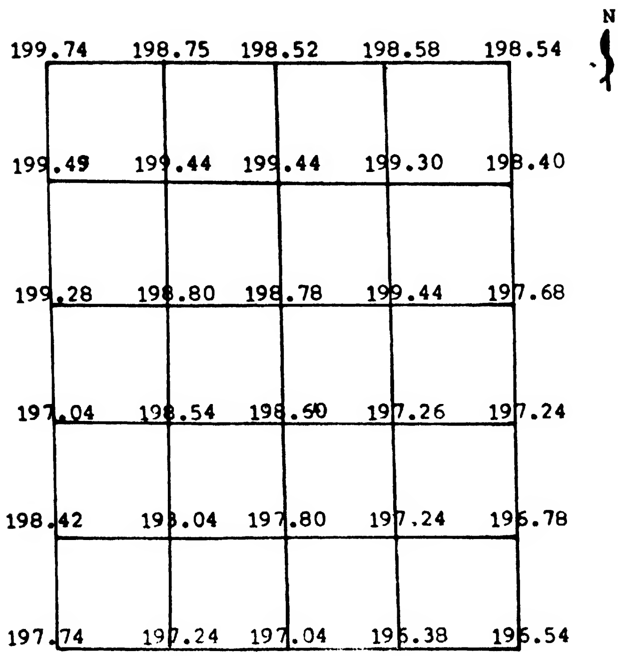


Fig. 7B. Grid Points and Contour Lines

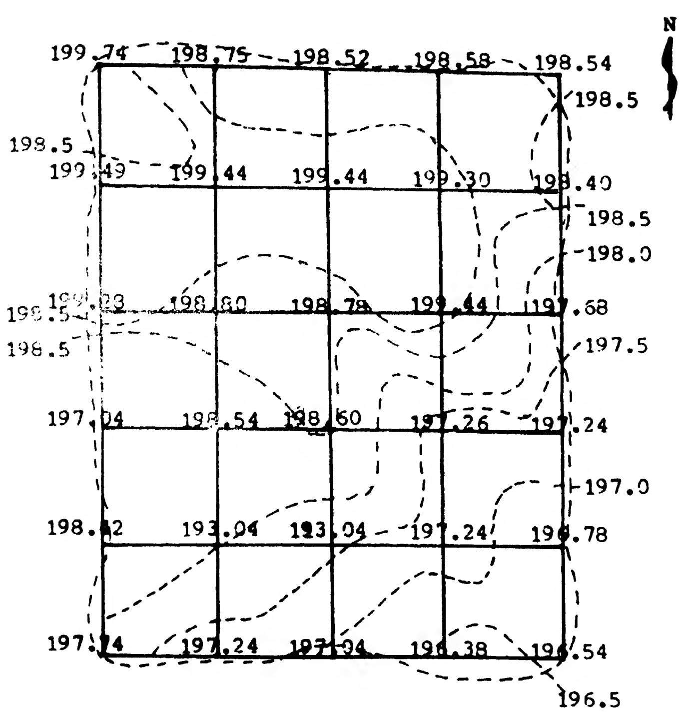


Fig. 7C. Grid Points and Contour Lines

From the above figures you will notice that the area enclosed by 198.00 m and 198.50 m; 199.00 m and 199.50 m contours has a flatter topography compared to the remaining area. In the north east side where the contour lines are spaced closely the topography is steeper. In this situation we can mark out two sites for main drains along the depressions i.e. along the lines AB and CD.

INTERPOLATION OF CONTOURS

To maintain the desired contour intervals, depending upon the slope, contour lines will have to be spaced out in the map by interpolation. The method is described below (Fig. 8) :

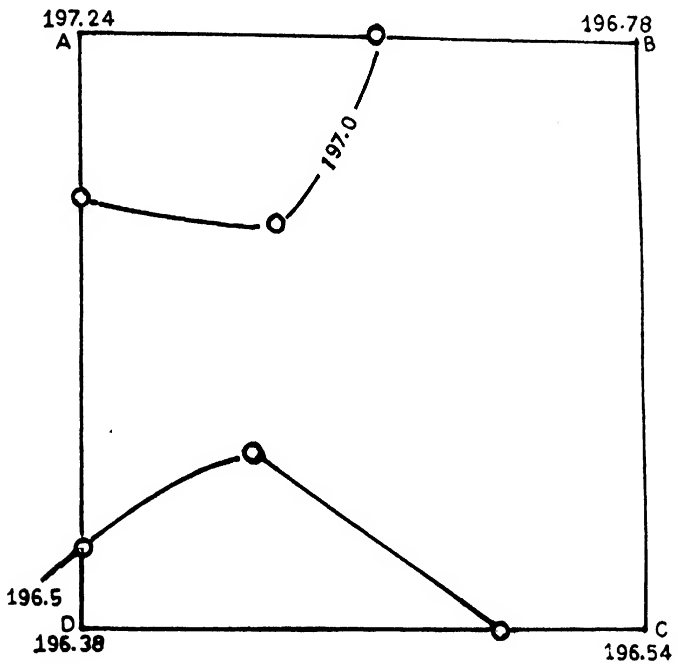


Fig. 8. Interpolation of contour lines.

For our discussions, let us take the area enclosed by 4 grid points from Fig 7. Here we see that grid point A has 197.24 m RL and grid point B has of 196.38 m RL. This means grid point A is higher than point B and the vertical interval between them is 0.86 m. Now within this square, we can draw two contours having 196.50 and 197.00 RLs. It is clear that the point 196.50 m RL is available on lines AD , BD

and DC. The line DC is divided into 50 parts for which the difference of level is 0.16 m(196.54-96.38) between points D and C. To locate the point of RL 196.50 we have to add 0.12 to RL 196.38 and, therefore, from D the point 196.50 m RL will be at 50 x 0.12/0.16, i.e, 37.5 divisions away from point D.The point of RL 96.50 m is then located on the line and marked. The line DA is divided into 50 parts and the difference of level between D and A is found which is 0.86 m.The point of RL 196.50 m is located similarly 50 x 0.12/0.86, 1.e. 6.97 divisions away from D.This point is marked on map.If we join the diagonal BD,to locate the point RL 196.50 on this line,it will be necessary to divide the BD line into 50 parts.But here the each part is / 2 times greater than each division along the line DA and DC. With the same method the point RL 196.50 m is located on BD line 50 x 0.12/04, i.e. 26 divisions away from D.This point is marked on map. These points can be joined by free hand to draw the contour of RL 196.50 m. Similarly along line AD the point of RL 97.00 will lie 50 x .

Now we need to draw the other contour of RL 197.00 m.From the above diagram it can be seen that the point of RL 197.0 m can lie on lines BA ,CA and DA only. The level difference between A and B is 0.86 m and to get the point of RL 97.00 m along line AB,we need to reduce 0.24 from RL 199.24.Therefore,the point of RL 197.00 will lie 50 x 0.24/0.86 i.e. 14 divisions away from point A in the line AB. The point of RL 197.00 along the diagonal AC,will lie 50 x 0.24/0.70 i.e. 17.1 divisions away from point A. These points than should be joined by free hand to draw the contour of RL 197.00.

LOCATION OF CONTOURS IN THE FIELD

After drawing the contours on topographical map,it is necessary to locate the contour lines on the ground so that we can use them for our purpose. For locating the contours on the ground with the help of the topographical map, the following procedures should be followed.

A bench mark is established near the site of the survey and then the level is set up in a commanding position and levelled accurately. The Height of Instrument(HI) is determined by taking a Back Sight(BS) on bench mark and additing it to the reduced level of the bench mark. From the known elevations of the contours and H.I., the required staff readings to fix points on the various contour lines(contour points) are obtained to the first place of decimal by substracting the elevation of each of the contours from the Height of Instrument.

SOME COMMON DEVICES USED IN DRAINAGE INVESTIGATION

H.GOSWAMI

INTRODUCTION

To layout an effective drainage system some investigations on soil and hydrological properties of the area are necessary. A faulty drainage system can cause an irrepairable loss to the land and productivity. Investigations, therefore, are required before installation of a drainage system. Some of the common devices which are normally used for such investigations are discussed below :

DRAINAGE INVESTIGATIONS

Drainage projects require survey and investigation of site conditions to determine their suitability for the purpose of drainage design. They are enumarated below :

1. **Topographic survey**
   A topographic survey map of the area showing all the topographical features are essential for drainage planning.

2. **Water table records**

   This investigation will give the fluctuation of water table during the rainy season which will indicate the extent and magnitude of water logging of the area.

3. **Physical properties of soil**

   Soil physical properties such as texture and hydraulic conductivity are important in designing drains with proper shape, side slope and spacing.

4. **Study of soil profile**

   Soil profile up to a depth of 1.50 m is required to find out the layerification and stability. These informations are used to decide the depth as well as the shape of the drain.

5. **Investigation on seepage flow**

   If there is seepage flow of water from a neighbouring area it should be intercepted by laying out an interceptor drain at proper location.

6. **Flood**

   Data on extent and frequency of seasonal flood should be collected. Average flood level and the highest flood level of the river or stream during the monsoon season should be recorded. The duration of the flood should also be known. This information is required to decide the depth of the main drain. This also gives a measure of the restriction of outlet provided we know the elevation of the area.

7. **Cost and benefit study**

The benefit of the proposed project should exceed the cost. Then only the project will be economically viable.

COMMON DEVICES USED IN DRAINAGE INVESTIGATION

1. **Observation well**

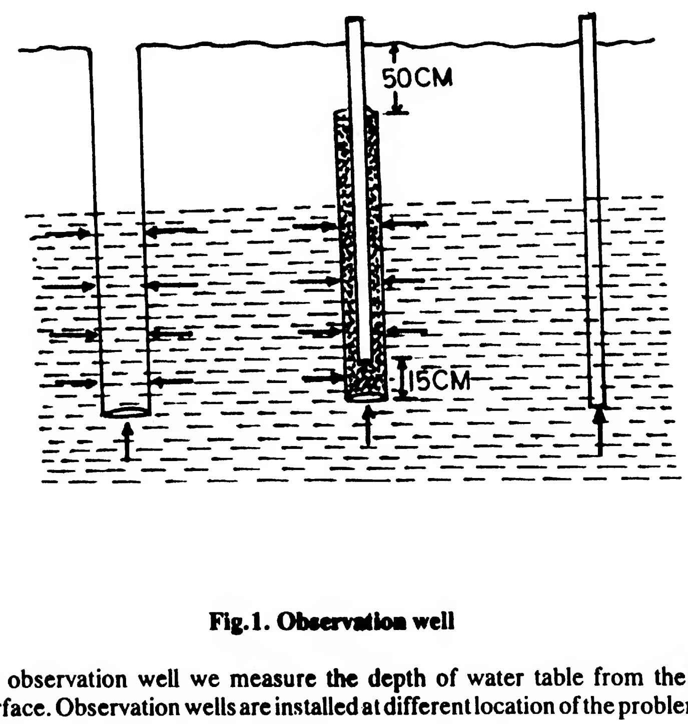


Fig.1. Observation well

By observation well we measure the depth of water table from the ground surface. Observation wells are installed at different location of the problem areas.

Installation of observation wells

(1) Use 100 mm (4") dia post hole auger with 3 meter extension rod.

(2) Make a hole, vertically straight, in the soil profile up to a depth of 2.50 m (8' approx.).

(3) Take 3 m (10') long PVC, rigid pipe of 25 mm (1") dia. Make 2 to 3 mm holes (with an umbrella stick) at 25 mm (1") spacing in 4 parallel rows along the pipe surface upto 2 m (6'6") leaving 1 m (3') at one end unholed.

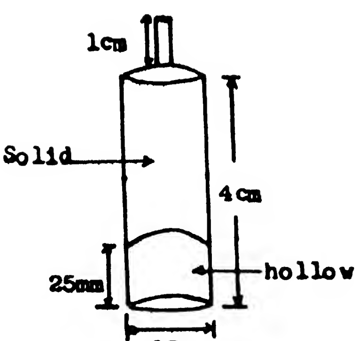
(4) Insert the PVC pipe with perforated side down into the auger hole in such a manner that upper 50 cm(1'8") long pipe appears above the ground and 2.50 m (8') length goes into the hole below the ground surface.

(5) Fill-up the annular space around the PVC pipe and below the pipe end with 12 mm (1/2") size clean gravel leaving upper 50 cm height, which should be filled with powdered top soil only.

(6) Ensure that the surface water does not enter the hole along the pipe walls.

(7) Of the 50 cm(1'8")projected upwards 20 cm (8") may be cut away so that only 30 cm (1') length is projected upwards.

(8) Water table will appear in the PVC pipe which can be measured with a suitable device (plopper) (Fig. 2)



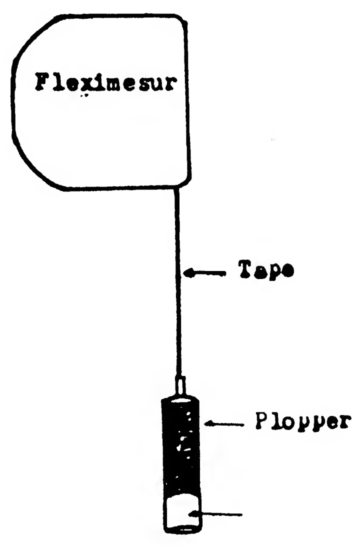


Fig. 2.

(9) Water table should be recorded at least once daily at a fixed hour, say, 9 O' clock.

(10) To see the efficiency of the drainage system one row of observation wells should be installed across the drain line. The row of OWs should pass through the mid point of the drain length. If water table of a large area is to be surveyed, OWs to be installed at 50 m or 100m apart by following grid system.

2. Automatic water table recorder

Water level recorder is a labour and time saving instrument for recording depth of water table automatically. With the rise and fall of water table a drum rotates and stylus moves horizontally with the help of a clock. Due to the combined action of those two a continuous water table recording is made possible.

Installation

(1) First a hole of 10 cm (2") dia is made with the help of a post hole auger.

(2) A slotted PVC pipe of 9 cm dia and 2.50 m (8') length is introduced into the hole so that about 50 cm (8") of the pipe is projected upwards. It should be fitted with the soil putting some gravels around it.

(3) A bamboo chang or a wooden table may be used to keep the recorder.

(4) The float of the recorder is allowed to rest on the water table inside the auger hole. A counter weight will balance the weight of the float..

(5) A recorder chart of 8 days interval is put around the drum of the recorder. The clock is winded.

(6) After 8 days the chart is taken out and replaced by a new one. In the chart a complete picture of the water table fluctuation during the 8 days period will be obtained.

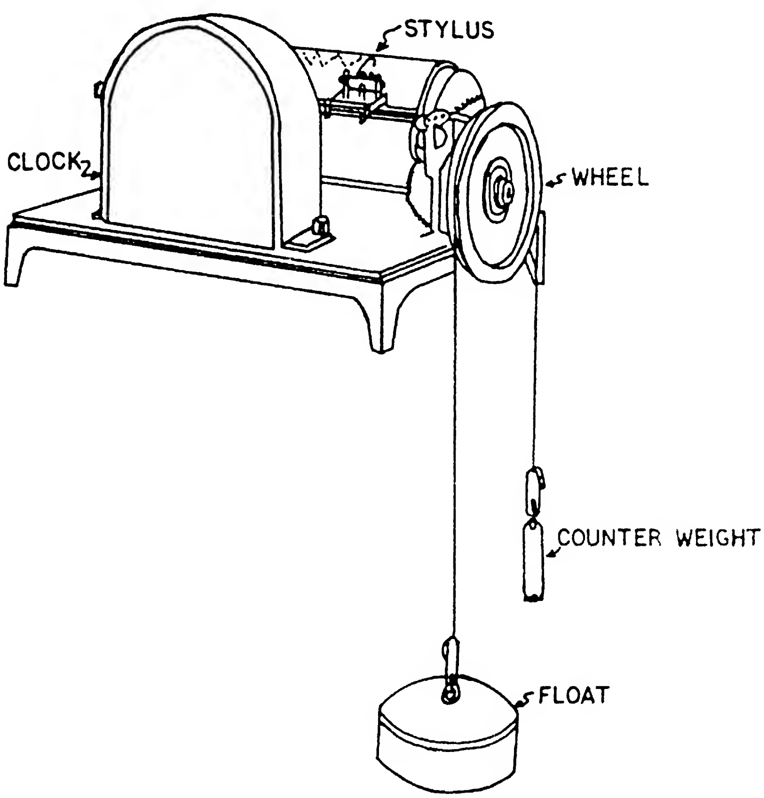


Fig. 3. Automatic Water Table Recorder.

3. **Tensiometer**

With the help of a tensiometer we measure the soil water tension. It consists of a tube fitted with a porous cup at the bottom and a vacuum gauge at the top. The whole system is filled with boiled and cool water.

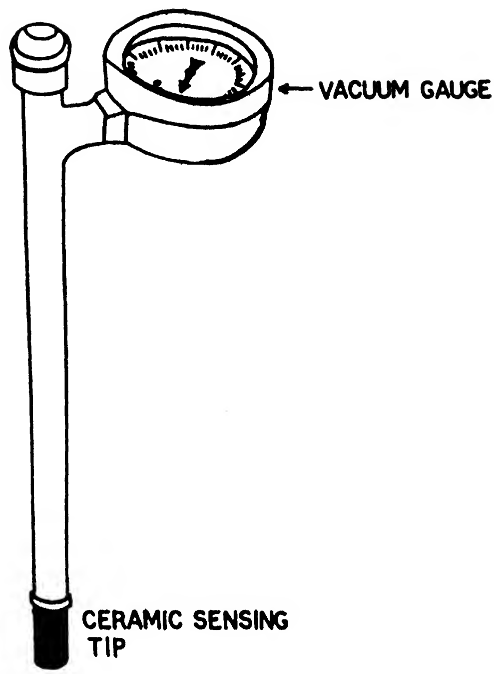


Fig. 4. Tensiometer

Installation

(1) Take a metal pipe which is 2 to 3 mm smaller in diameter than the tensiometer diameter.

(2) Hammer the metal pipe vertically straight into the soil gently without disturbing the soil to a depth that is 15 cm (6") less than the actual length of the tensiometer body.

(3) Pull out the metal pipe with soil carefully leaving behind a straight undisturbed hole in the soil.

(4) Push the tensiometer body with its porous cup at the end gently into the hole to its full length.

(5) Press the soil around the tensiometer body firmly so that no surface water can enter the soil along the tensiometer body.

(6) Take reading of soil moisture tension daily at a prefixed time, say 8 a.m. or 9 a.m.

(7) Reading between 0 and 0.1 show moisture above field capacity, 0.1 to 0.8 show available moisture and beyond 0.85 the instrument cannot measure the tension. This instrument is therefore useful for wet to moist range of soil moisture.

(8) Start irrigation when 60 cm deep tensiometer reads 0.50, 0.55 in case of loamy sand, sandy loam and loam texture, respectively.

(9) With 4 to 12 hours of irrigations, the tensiometer reading shall come to 0.10. A reading higher than 0.10 means that area was underirrigated and the reading lower than 0.10 means that area has been overirrigated.

(10) For desired results, install 3 tensiometers in one place at 30, 60 and 90 cm depth to monitor the distribution of moisture in entire root zone.

5. Rain gauge

The raingauge recommended by the Indian Meteorological Department consists of a funnel shaped collector, a polythene bottle and a graduated measuring cylinder. For North East Indian condition a 200 sq. cm. collector is used. A four litre bottle with a capacity of 200 mm is used because the catch in a 24 hour period is not expected exceede this value.

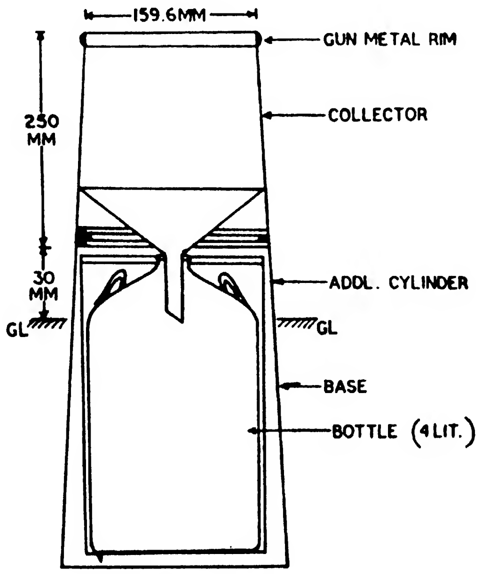


Fig. 5. Raingauge

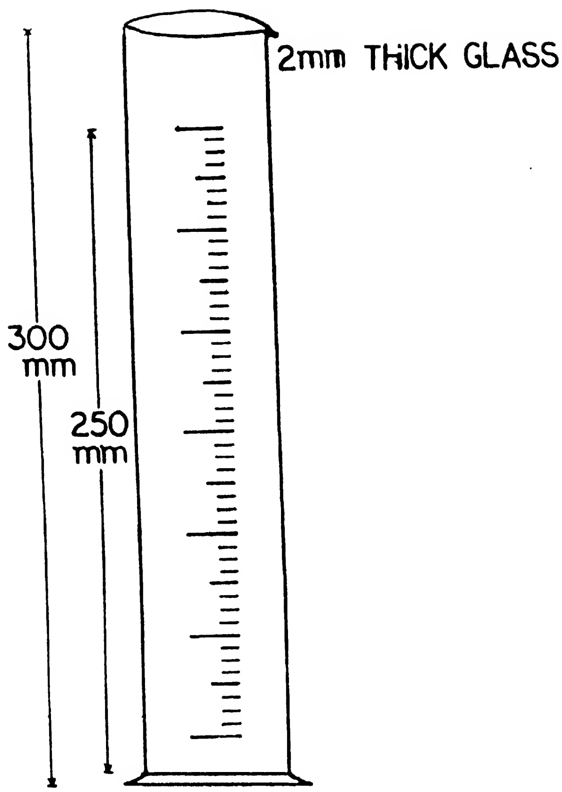


Fig. 6. Measuring cylinder

Installation

(1) The rain gauge should be installed on a level ground.

(2) It should not be installed near a tree or a house or any other structure.

(3) The distance between the nearest object and the rain gauge should not be less than twice the height of that object.

Measurement of rainfall

(1) Rainfall is measured by a measuring cylinder which is graduated in mm..

(2) Collectors of various sizes have got different measuring cylinder. Therefore care should be taken so that right type of cylinder is used for a certain rain gauge.

(3) The routine time for rainfall observation all over the country is 0830 (IST).

Automatic rain gauge

Automatic rain gauge keeps continuous records of quantity of rainfall as well as its intensity.

Infiltrometers

Infiltrometer measures infiltration rate of water into the soil. Infiltration rate is the time rate at which water will percolate into the soil. This rate is influenced by soil properties as well as moisture content of the soil.

Installation

(1) Infiltrometer has two metal cylinders. Inner cylinder is 30 cm in dia and 30 cm high and the outer cylinder is 46 cm in dia and 30 cm high. The wall thickness of the cylinder shall be 5 mm.

(2) Install both the cylinders with small one inside the bigger, by hammering gently in a level land to a depth of 15 cm. Ensure that soil is not disturbed during installation.

(3) Fill up both the cylinder with water slowly to a depth of 10 cm without disturbing the surface soil.

(4) With the help of a point gauge, record the recession of water in the inner cylinder at different timings for about 60 mts period.

(5) Plot the water level data with respect to elapsed time and fix the curve (Fig.8).

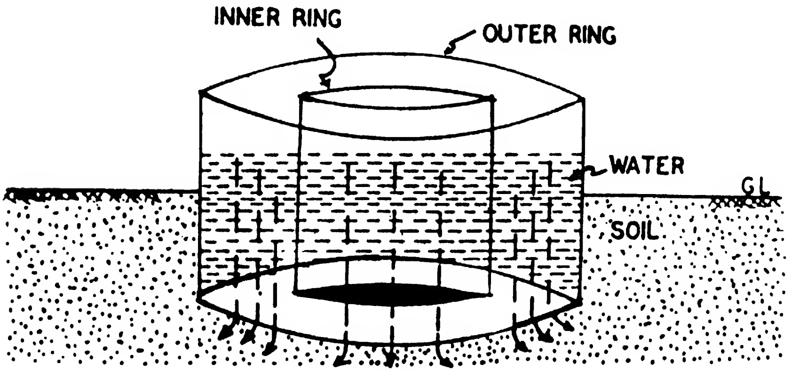


Fig. 7. Infiltrometer

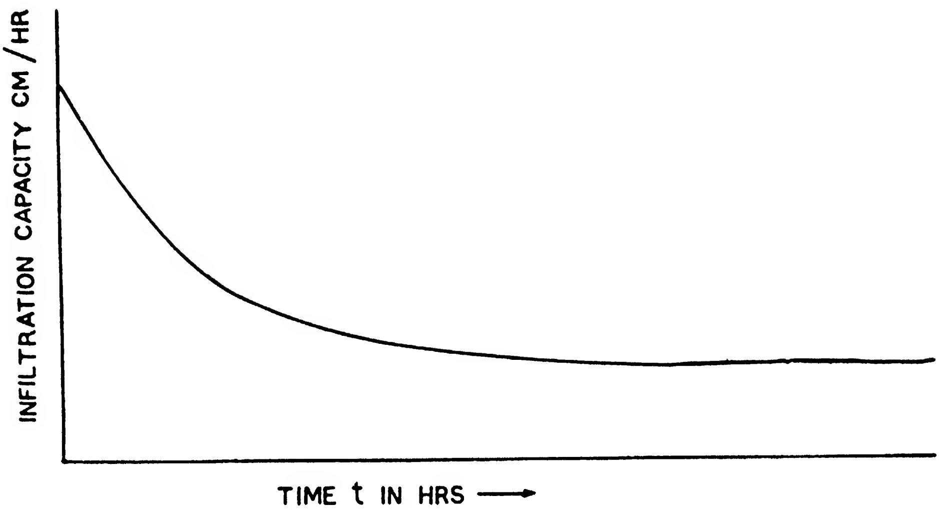


Fig. 8. Infiltration curve.

(6) After some time the infiltration rate will be steady and this steady value is taken as the infiltration rate of the soil.

DESIGN PARAMETERS OF DRAINAGE SYSTEM AND DESIGN OF MAIN DRAIN

P.K. BORDOLOI

INTRODUCTION

In this chapter I shall deal with the type of informations to be collected for planning of drainage system for tea cultivation, as well as a sample problem as to how to use these informations for designing the main drain.

The influence of topography on movement surface as well as sub-surface water is already discussed. We have also learnt how to collect topographical information through level survey and prepare contour maps. Other informations that are to be collected are rainfall of the area-its intensity and duration, water table and its fluctuation, texture of the soil and its hydraulic conductivity.

DESIGN PARAMETERS

Usually tea estate drainage layout consist of main drain, collector drain and field **drains. Their** functions are as follows:

Main drain — to carry the excess water to the outlet. It drains the entire catchment.

Field drains — to encourage flow of excess soil moisture from root zone quickly for ventilation of the root zone, in addition of surface run off.

Collector drains-to collect the discharge of field drains and carry to the main drain.

1.0. **Capacity of drains:**

The size of main drain should be adequate to carry the runoff. Therefore, it is necessary to determine first the volume of water to be drained from the catchment. There are several methods to determine runoff, out of which for simplicity rational formula is popularly used.

$$Qp = 0.0028\ CiA$$

Where

Qp=peak runoff rate in cumec (m^3/s)

C= runoff co-efficient

i= rainfall intensity in mm/hr for the design return period for a duration equal to the 'time of concentration' of the catchment.

A= area of catchment in hectares

1-1. **Runoff co-efficient:**

Runoff co-efficient is defined as the ratio of the peak runoff rate to the rainfall intensity and is dimensionless. Its value is dependant on infiltration rate, surface cover, slope of land rainfall intensity. Some of the values for different soil type-are presented in Table1.

Table 1 : Run-off co-efficients for various situations for estimating peak flow rate (developed in U.S.A. and adopted elsewhere).

Slope	sandy loam	silt loam	heavy clay
Forest			
0-5 %	0.10	0.30	0.40
5-10 %	0.25	0.35	0.50
10-30 %	0.30	0.50	0.60
Arable Land			
0-5 %	0.30	0.50	0.60
5-10 %	0.40	0.60	0.70
10-30 %	0.50	0.70	0.80

1.2 Rainfall intensity and design storm:

To get an insight into rainfall intensity for design purposes, storm over a long period of time (10-20 yrs) were scanned. Storms of short duration, although of higher intensity, were neglected, as the time of concentration for average size tea garden exceeds those duration. For design purpose we need rainfal duration atleast equal to or exceeding the time of concentration of the catchment which falls at an uniform rate thoughout. Higher is the return period-more intense is the rain and lower the return period intensity of rainfall is less. If drains are designed for lesser return period rain, then the capacity of drain be small which may result in inundation of the areas. With higher return period, size of drain will be a bigger one. Keeping this fact in view and economic life of the plants, twenty and five year return period rainfall is chosen for design purpose for gravity drainage and pump drainage respectively.

1.3. Time of concentration (TC):

It is the time taken by water to flow from the most remote (in time of flow) point of the area to the outlet. At the time of concentration whole catchment contribute simultaneously to the discharge at outlet. TC can be calculated by the following formula:

$$TC = 0.0195 \times L^{0.77} \times S^{-0.385}$$

TC = time of concentration in min.

L = maximum length of flow in m.

S = watershed gradient in m per m.

Table 2: Change in time of concentration with respect to slope of land and length of travel :

Slope	Time of concentration in min. / Travel length in m.		
	3000	5000	7000
.001	132	196	254
.002	101	150	194
.01	55	81	105
.02	42	62	80

Design of main drain:

The main drain design includes-designing the shape of drain, fixing size of drain and depth of flow. The requirement of main drain design is therefore-

(1) Maintaining non-silting non-scouring velocity of flow.

(2) Sufficient capacity to carry design flow.

(3) Adequate side slope to prevent caving into the drain.

2.1 **Depth of drain:**

Field drains or laterals require a minimum depth of 105 cm so as to lower the ground water below 90cm. The depth of main and sub-main drains should not be less than 150 cm and 120 cm respectively.

2.2 **Velocity of flow and bed grade:**

The velocity of flow in an open channel is governed by slope of the channel, flow area, wetted perimeter and resistance offered against the direction of flow. Manning equation may be used to determine the permissible velocity of flow:

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

where- V = maximum permissible velosity m/sec.
S= hydraulic gradient (bed slope)
R= hydraulic mean depth in m = A/P
A= cross-sectional area of flow, sq.m.
P= wetted perimeter, m.
n= manning's roughness co-efficient.

Table 3 : Manning's co-efficient for different bed material.
(Adopted from Fortier and Scobey)

Drain bed material	Value of n
Fine gravel	0.020
Sandy loam	0.020
Silt loam	0.020
Fine silt loam	0.025
Coarse gravel	0.025
Loam with cobbles / gravels	0.030
Cobbles and shingles	0.035

Maximum permissible velocity for different soil texture is presented in table 4.

Table 4. Maximum permissible mean flow velocities in unprotected canals with suspend load.

(Adopted from Fortier and Scobey 1926, 'Permissible canal velocities')

Bed material	Velocity m / s
Fine sand	0.75
Sandy loam, silty loam, silt	0.75-1.00
Loam	1.00-1.10
Clay	1.50
Gravel (fine- coarse)	1.50-1.80

Bed Grade: The drain bed grade is determined largely by the natural slope of the lan drain depth and elevation of the outlet. From the Manning's equation it can be seen th steeper is the gradient velocity will be higher for the same cross-section. But excessi gradient should be avoided, because high velocity induces scouring. Conversly, low gradient reduces velocity of flow. This causes silting to take place. Normally bed gra usually ranges from 0.05 to 0.5% i.e. 5 to 50 cm drop in 100 m run.

2.3. **Drain Shape:**

The gradient of a drain bank is called the batter. Drains should have sufficient batt to ensure that its sides donot collapse. Steeper batter may allow the banks to collap into the channel and this is called bank slip. Drains should be excavated with a batt that is less steep than the natural angle of repose of the bank forming material. Tl suggested satisfactory batter for different types of soils are given below:

Table 5 : Side slope for open drains in tea soils.

Soil type	Side slope Vertical distance : Horizontal distance
Loamy sand	1 : 2
Sandy loam	1 : 1.5
Silt loam, loam and clay loam	1 : 1

2.4 Bottom width:

After the channel grade, depth and batter is selected, the bottom width for the efficient cross-section can be determined by the following formula:

$$b = 2d \tan \frac{\phi}{2}$$

where, b = bottom width
d = design depth
ϕ = side slope

3. Spacing of field drains :

There are several drain spacing formulae out of which Hooghoudt's formula is widely used.

$$S^2 = \frac{4\ K\ Hm}{Q}(2\ d + Hm)$$

where S= drain spacing, m
K= soil hydraulic conductivity, m /day
Hm= height of water table at mid point between the two drains above the bed level of the drain,m
Q= drainage coefficient, m /day
d= equivalent depth to impervious layer below the drain bed level, m.

The graphical represantation of Hooghoudt's formula is shown below: Fig. 1.

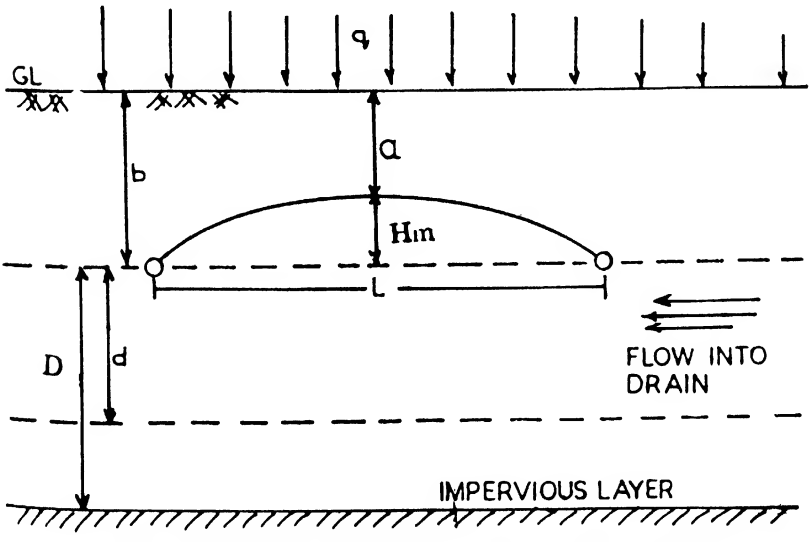


Fig. 1 Graphical representation of Hooghoudt's equation

3.1 **Equivalent Depth (d):**

The soil layer which is having a hydraulic conductivity value one tenth that of the top layer is defined as impervious layer and depth of this layer below the drain bed level is known as depth to impervious layer. This can be examined by digging holes and determining hydraulic conductivity of different layers. Accordingly from this depth De can be find out from standard table.

3.2 **Hydraulic conductivity (k):**

Hydraulic conductivity is defined as the velocity of flow of water through the soil under unit potential gradient and is expressed as m/day. This can be determined by auger hole method. This method consists of digging a hole with an auger which extends below the water table. When the water table inside the hole is in equilibrium with ground water table some water is bailed out to lower the level of water in the hole and the subsequent rate of rise of water in auger hole is then measured. This rate of rise depends on hydraulic conductivity of soil, geometry of the hole and the height of water table. Hydraulic conductivity of different types of soil is presented in Table 1.

Table 6 : Hydraulic conductivity values for different soil tetxure :

Soil texture	Hydraulic conductivity (m / day)
Loamy sand	2 - 3
Sandy loam	0.85 - 1.50
Loam	0.50 - 0.75
Silt loam	0.30 - 0.50
Clay loam	0.20 - 0.30
Clay	less than 0.20

4. **Drainage Co-efficient (Q) :**

Drainage co-efficient is the amount of water to be drained out from a catchment area in 24 hour period . It is expressed in mm/day . Drainage co-efficient depends on the rainfall rate and the amount of surface and sub-surface run off which is admitted to the drainage system. The size of the watershed also affects the drainage co-efficient. Drainage co-efficient can be determined by field experiments.

Table 7 : Average design specification of drains in medium texture-soil (sandy loam type).

Drain	Drain depth cm.	Bottom width cm.	Min. desirable bed grade %	Depth of flow cm.
Subsidiary	105	15-20	0.25	10
Collector	120	30-50	0.15	15
Sub-main drain	150	50-100	0.10	30

For spacing of field drain in case of slopped topography the design criteria is described elsewhere.

DESIGNING OF MAIN DRAINS :

Exercise :

Now with the formula given before, let us design a main drain for a catchment having the following informations :

1. Area of catchment	200 ha.
2. Topography	flat 0.1 to .15% slope
3. Texture of soil	Sandy loam / loam
4. Maximum length of travel	3000 m
5. Difference of elevation	3 m

Solution :

Step I. Peak discharge

$$Q = .0028\ CiA$$

$$C = 0.3$$

$$Tc = .0195\ L^{.77}\ S^{-.385}$$

$$S = 3 / 3000$$

$$= .001$$

$$Tc = 132 \text{ min.}$$

Intensity of rainfall $= 45$ mm / hr (for South Bank)

$= .0028 \times .03 \times 45 \times 200$

$= 7.5\ m^3/s$

Step II. Allowable velocity $= 0.9$ m /

$$Q = AV$$

$$A = \frac{7.5}{0.9}$$

$$= 8.33\ m^2$$

Step III. Hydraulic radius (R) can be determined from Manning's equation-

$$Q = AV$$

$$= A \frac{1}{n} R^{2/3} S^{1/2}$$

$$7.5 = \frac{8.33}{0.025} \times R^{2/3} \ .001^{\frac{1}{2}}$$

$$R^{2/3} = 0.712$$

$$R = 0.60\ m$$

Step IV : Determination of depth of flood (d): with such a high value for A and low value for R, it is not possible to find a solution. Therefore, R value should be increased by changing the bed grade.

Let us assume a cross-section with bottom width b = 6.0 m, side slope 1 : 2 and depth of flow d = 1.0 m .

Area of the section $A = (6 + 2 \times 1) \times 1.0$

$= 8.00\ m^2$

Welled perimeter $P = (6 + 2\sqrt{1+2^2} \times 1.0)$

$= 10.470$ m

Hydraulic radius $$R = \frac{A}{P}$$

$$= \frac{8}{10.470}$$

$$= 0.764 \text{ m}$$

For this hydraulic radius , to maintain the permissible velocity of flow, the bed slope be changed -

$$AR^{2/3} = \frac{Qn}{S}$$

$$8 \times .764^{2/3} = \frac{7.5 \times .025}{S}$$

$$S = .0008$$

$$= 0.08\%$$

PLANNING AND IMPLEMENTATION OF DRAINAGE SYSTEM IN FLAT LAND INCLUDING ESTABLISHED TEA

P.K. BORDOLOI

INTRODUCTION

Sub soil drainage is defined as the removal of water from the root zone by lowering the groundwater table. It can be achieved by correctly spaced deep open drains, underground pipe drains or by a combination of both.

Shallow open drains were provided in tea areas in the past to collect the surface runoff but the current practice is to have deeper drains to drain the sub soil water as well. Therefore, as far as possible, the drains are being deepened depending upon the availability of outlet. The design of suitable drainage system requires information about soil, topography, source of excess water and amount of excess water. The preliminary survey of the proposed drainage project in an estate is, therefore, an important initial investigation to avoid further complications that may come up at the later stages of planning a drainage system.

PRELIMINARY SURVEY

The survey should include the following aspects :

(i) Land topography- natural depressions and waterways etc.
(ii) Soil properties-texture, structure, permeability, porosity, bulk density etc.

(iii) Outlet availability- distance of natural outlet from drainage area, average water level of the outlet during monsoon and elevation of most low lying areas to be drained.

(iv) Source of water- such as: rainfall, runoff, seepage and deep percolation data.

(v) The flood level of the drainage base (AWL, HFL, its duration and frequency).

(vi) The size and location of bridges, culverts, rivers, P.W.D. roads and railway lines.

(vii) The size of the area to be drained.

The topographic survey is an essential pre-requisite for a drainage system. The soil properties affect the shape (cross-section), side slope, and bed grades of the drain.

The information regarding availability of outlet helps in deciding the type of outlet, e.g. gravity, pumped or both

The drainage system is then designed and drain spacings are calculated. The design requirement and procedure followed are as follows :

DESIGN OF OPEN DRAINS :

A properly designed drainage system should provide the following conditions :

(i) velocity of flow should be such that neither serious scouring nor sedimentation will result.

(ii) sufficient capacity to carry the design flow.

(iii) hydraulic grade line low enough to drain the land.

(iv) side slopes will not cave-in or slide into the drain.

The design of an open drainage system includes mainly the shape, size, depth, bed grade, side slope, alignment, junctions and spacing of drains. We have already discussed how to design the main drain. Let us discuss about alignment,junctions and location of the drains.

1. Alignment of main drain

Proper alignment includes the design of straight drains and, wherever necessary, gradual curves to prevent excessive bank erosion.

2. Drain Junction

The junctions of the drain with another should be such that serious bank erosion, scour holes, or sedimentation will not occur. The laterals should be designed to enter the larger drain at an angle less than or equal to 90 degree with the direction of water flow in the larger drain.

3. Drain location

After the drainage system has been designed, one can proceed with the field layout. The general location and alignment of the drains has normally been determined by the preliminary survey. A few general rules for locating the drains are given below :

(i) For main drains, and sub-main drains, follow the general direction of natural waterways.

(ii) Large size drains should be straight as far as possible or with gradual curves, if required.

(iii) Locate a drain along the estate boundary, if practicable.

(iv) Make use of existing drainage system as much as possible.

(v) Avoid locating drains in a place where it will require expensive structures and maintenance.

TYPES OF SURFACE AND SUB-SURFACE DRAINAGE

Depending upon the situation, both surface and sub-surface land drainage can be done by any of the following methods :

1. Parallel /Gridiron system
2. Herring bone system
3. Random drainage system
4. Interceptor

PARALLEL / GRIDIRON SYSTEM :

In flat areas where the slope is not more than 0.45 % the parallel / gridiron system of drainage is most suitable. In this system the lateral field drains are provided across general direction of the slope of the land. The collector drains run perpendicular to the lateral field drains i.e. along the slope, collecting water from these drains and ultimately discharge into the main drain. The main drain is generally located in the lowest portion of the area, usually along the boundary.

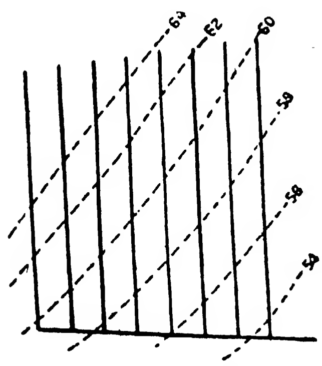


Fig.1. Grid Iron

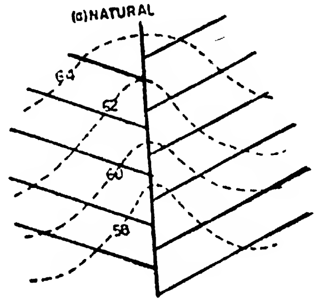


Fig. 2. Herring Bone

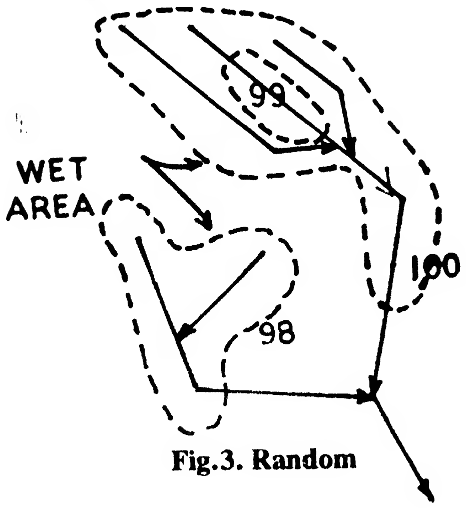


Fig.3. Random

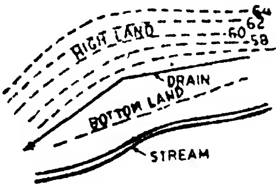


Fig.4. Interceptor Drain

HERRING BONE SYSTEM :

Herring bone type of drainage system is generally provided under situation where the land slope does not exceed 0.50%. In this system usually the length of the collector drain is long and the lateral field drains are short. While draining in this system, the lateral field drains are dug oblique to the general direction of the slope of the land and the collector drain which collect water from these drains is provided along the natural depression. However, since this type of drainage does not provide full protection against soil erosion, it is generally not recommended for tea areas having more than 0.5% slope.

RANDOM DRAINAGE SYSTEM :

The random drainage system is generally used to drain isolated wet places or to 'tap' springs by providing a combination of lateral field drains, collector drains at random. In this system the lateral field drains of varying length are provided along the isolated wet pockets which are then connected to the nearest collector drain along the natural depressions.

INTERCEPTOR DRAIN :

This drain is provided near the upper edge of wet area to intercept seepage flow to the wet area.

Drain Construction :

Digging of the drain should start at the outlet and proceed upgrade. The main drains should be dug first, followed by sub-main drains, and then the laterals.

Spoil banks :

The spoil bank (excavated soil) of all the drains should be spread evenly over the area.

Period of drain construction :

The period of drain construction is mainly decided on the basis of the degree of soil wetness. Digging should be avoided in wet soil conditions. The best period for digging drains in this region would be the cold weather i.e. November to March / April.

Length of drain :

On level lands, a drain on a slope of 0.15 per cent, will drop 30 cm in 200 metres, and this distance becomes about the maximum permissible length of the drains. Similarly, a drain laid out on a slope of 0.05 per cent will drop 30 cm in 600 metres, and this disctance becomes about the maximum permissible length of the drains in this case.

CAUSES OF DRAIN FAILURE :

It is difficult to keep open drains operating efficiently in unstable and loose soils. Major causes of their failures are :

(a) Sedimentation in the drain channel :

Most of the sediment that comes into the drain is due to erosion of the surrounding land and scouring within the drain itself. Soil scouring and siltation in the drain occurs if the bed grade is not adequate and uniform throughout the length of the drain.

(b) Improper location and alignment of drains :

It causes serious bank erosion of the drain. In unstable soil even the gradual turns may not be able to eliminate erosion in the drain.

(c) Improper junctions :

Improper junctions of one drain with another and overfall at the junctions cause serious bank erosion, scour holes or sedimentation in the drain.

(d) Inadequate size and shape of the drain :

The deep drains (depth more than 90 cm) dug in the available space between two tea rows do not usually meet the design requirement of a drain.

Such drains will require regular maintenance if they are to do the job they are meant for .

(e) Inadequate culvert and bridge capacity

(f) Improper land use on the watershed

(g) Excessive growth of weed in the drains

(h) Blockage of natural waterways/outlet drains.

It is clear that in many situations it would be extremely difficult to keep the open drains operating effectively, particularly in unstable soils, withought regular maintenance. In order to control the water table 90 cm below the ground surface the leteral drains will have to be 105 cm deep (minimum). The deep drains with trapezodial cross section will occupy much valuable land. A great deal of unnecessary and expensive maintenance is caused by faulty drain construction in unstable soils. Many cases are seen of collapsed drain sides as a result of not having proper design. It is therefore, becomes important to find out the possibilities of an alternative drainage system for unstable and loose soils where deep open drains with nearly vertical sides fail to work effectively. One alternative, which is being evaluated at Tocklai, is the underground pipe drainage system.

It is realised from literature that in comparison to open drains the pipe drains require less maintenance. The pipe of adequate size laid at a required grade with properly designed envelope material will cause no problem of siltation or deposition of sediments in the drain. However, the areas where springs feed the pipe drains, the roots of shade trees and tea bushes may grow into the pipe and obstruct the flow; in suchcases,thedrain pipes have to be cleared periodicaly. Most important is the high initial cost ot pipe drainage system which must be considered carefully before this is adopted.

DRAINAGE DESIGN AND PLANNING IN ESTABLISHED TEA

Poorly drained areas in established tea can be improved to a great extent by careful planning and modifying the existing drainage system wherever possible. The modification of the existing drainage system is dictated by the topography of the area under consideration and must not involve unnecessary uprooting of bushes.

More often than not the existing tea usually suffer from the following drawbacks as far as land drainage is concerned :

1. Faulty alignment of drains.

2. Undersize culverts and bridges.

3. Inadequate size and shape of main and outlet drains.

4. Undersize and depth of main outlet drains.

5. Inadequate or restricted outfall.

DRAINAGE LAYOUT PLANNING

Before planning a modified drainage system in established tea, knowledge of the water table below the ground level is necessary. By digging inspection pits or by installing observation wells along the general direction of slope and along the main drains the watertable should be recorded from June to September. A high watertable during this period is an indication of waterlogging and non-functionl of the drainage system.

The network of the existing subsidiary and the main drain and the condition of the outfall should be examined to locate means to carry away the excess water and the points where the water will be discharged ultimately.

Next, a layout and a existing drainage survey maps of the area will be necessary before finalising the drainage project. The map should show the following clearly :

1. Boundaries of the proposed area to be drained.

2. Existing drains.

3. Contours indicating the depressions, natural waterways, crests or ridges, etc.

4. Location and elevation of possible outlet and their water levels during monsoon.

5. Areas from outside that will drain into each part of the system.

6. Location of rivers, hullahs and their points of highest flood levels.

7. Location of roads, paths, culverts and bridges with their dimension.

Once the above informations are avilable, on the basis of the topographical map, the entire area should be divided into major natural catchments and these should further be divided into minor natural catchments. These minor natural catchments will again be divided into man made catchments. Once the size of catchments area is known, it will be possible to calculate the dimension and gradient of main and submain drains for efficient disposal of water from the catchments.

PLANNING SUB SURFACE DRAINAGE

Alignment

If the alignment of the subsidiary or field drains is faulty, best efforts should be made to retain some the existing drains and develop them at suitable intervals into primary or collector drains. New subsidiary drains should be provided across the general direction of the slope. These drains should be as far as possible straight but every efforts should be made to align them along the tea rows. These drains should be connected to the primary or collector drains and ultimately they will discharge into the perimeter or main drains. Perimeter drains should be provided to cut off the seepage flow from the nearby catchments and these should be best aligned along the sectional boundaries. In hilly slopes these drains should be provided at the base of the slope to intercept seepage flow from the high lands.

Siting of drains

Siting of the drains is very important as drains placed on wrong site will cause more harm than good. In the same section, there may be slope in different directions and under this situation the field drains should be provided across the general direction of the slope and they should be as near as possible parallel to the contour. In undulating topography isolation of interceptor drains are necessary at the base of the slope to prevent seepage flow from the high lands.

Digging contour drains in established tea will entail uprooting of a large number of tea bushes. To avoid uprooting tea bushes, the field drains should be laid out diagonally or along the tea rows.

In flat areas under tea, the existing drainage system can be modified in grid iron system where the drains are straight and parallel. This will avoid uprooting of large number of bushes. In this system, the roadside or the periphery drain of the tea sections can be easily converted into sub main or collector drain.

In moderately undulating triangular planted section(s) where the slope is oblique i.e. it is slanting, the existing drains can be aligned like a herring bone where the field drains will be aligned almost parallel to the tea rows. In this system of drainage the uprooting of tea bushes will be minimum.

More often than not in tea estates, the low lying pockets create waterlogging problem and tea in these pockets is extremely weak. To drain out these low lying pockets random system of drainage should be provided where collector drains are dug in the middle of the depressions and connected to the submain drains. These drains are narrow drains and while digging, uprooting of tea bushes may not be necessary.

Drain depth:

In slope where rising of watertable is not a problem, 30-45 cm deep graded contour drains will be sufficient. However, in case of high watertable, the graded contour drain should be deepened to a depth of 105 cm and connected to 120 cm deep collector drains.

In sections with flat topography, the depth of drain will depend upon the availability of outfall. The idea is to deepen the field drains sufficiently so that they are able to drain out the subsoil water efficiently. Therefore, the depth of field drains should not be less than 105 cm. For main and sub main drain a minimum depth of 120 cm and 150 cm should be maintained.

Main Drains, Culverts and Bridges:

The size of main drains, culverts and bridges should be worked out on the basis of catchment area, rainfall, soil type etc.
Where further deepening is not possible, the main drains should be adequately widened to increase the volume of outflow.

Restricted outfall :

Under condition of restricted outfall or back pressure due to highest flood level during monsoon, it will be necessary to construct sluice gates at the vulnerable spots. In low lying areas where the force of gravity fails to dispose off the drainage water, it may often be useful to guide the drainage water into sumps dug in the lowest point and pump out the water as and when required during the critical periods. To prevent inflow of water from outside, perimeter drain along the boundary with a bund will be necessary.

PIPE DRAINAGE PLANNING AND INSTALLATION TECHNIQUE

D. N. SAIKIA

INTRODUCTION

Tocklai has been working on the scope and need of pipe drainage in tea under some specified situations. Infact considerable knowledge on the plan and techniques of laying out underground pipe drains have been gathered in these years and adoption of this system in flat land proved to be economically feasible in tea estates.

SCOPE OF PIPE DRAIN

In the conventional system of drainage only 90 to 100 cm deep open drains are dug at a spacing of about 10 to 15 m. This is widely followed in the tea gardens. However, where the soil texture is light, deeper drains are not stable and in such areas shallow subsidiary drains of 60 to 65 cm depth are very common. These drains mainly function as surface drain to take care of run off water and are far from satisfactory in dealing with the sub-surface drainage. It is, therefore, essential to provide deep field drains to drain out the excess water from tea root zone. But it may be sometimes difficult and expensive to keep such deep drains working particularly in unstable and sandy type of soil. In such soils cave-in of drain walls is very common which ultimately causes failure of the entire drainage system. Maintaining proper grade in the drain bed in sandy soils is also another problem in open drainage system. Improper grading leads to scouring of the drain bed and enhances erosion and siltation in the drain. Over and above recurring maintenance is essential for best functioning of open drains. Except in heavy soils vertical sides of drains are not stable and it is necessary to dig the drains with sufficient side slopes to ensure that drain sides do not collapse. Thus, the deep drains with trapezoidal cross-section will take away a considerable amount of valuable land from planting. In such unstable and sandy type of soils, adoption of underground pipe drains will be a better proposition even though its initial cost is comparatively higher.

ADVANTAGES OF PIPE DRAIN SYSTEM

1. Maintenance

In pipe drain system caving-in and scouring of drain beds do not take place and, therefore, recurring maintenance cost is drastically reduced. Desilting, weed control and regrading operations etc. which are necessary in open drain systems are totally eliminated in pipe drain system.

2. **Land removal**

Since the trenches dug in pipe drain system are filled back, there is no land loss due to drainage. Even on the top of the drain, tea can be planted. This favours movement of machines like plucking machines in field. Land saving to the extent of 5 to 6 per cent is possible under pipe drainage system.

3. **Improper junction of drain**

Alignment of the lateral drains in the collector or sub-main drain in open drain system is an important point to consider. Improper alignment may cause collapse of drain walls at junction point. In pipe drain system the last end of the pipe protrudes out from the drain side wall and the water is discharged directly in the drain bed of the collector or sub-main drain. That is why, possibility of giving improper junction of drain is remote in a pipe drain system. Figure 1A and 1B show the ideal junctions for open and pipe drain respectively.

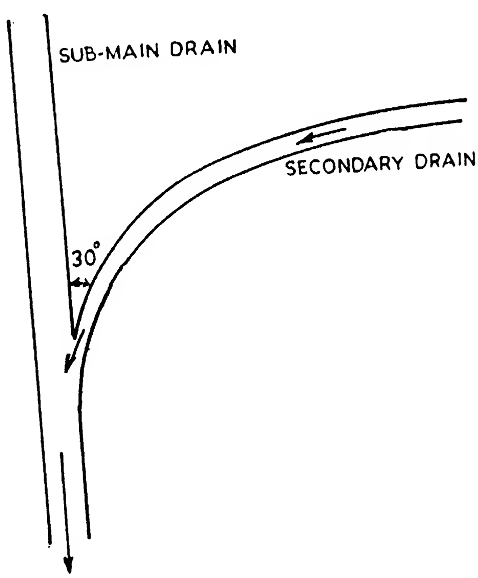


Fig. 1A The junction of secondary and sub-main drains

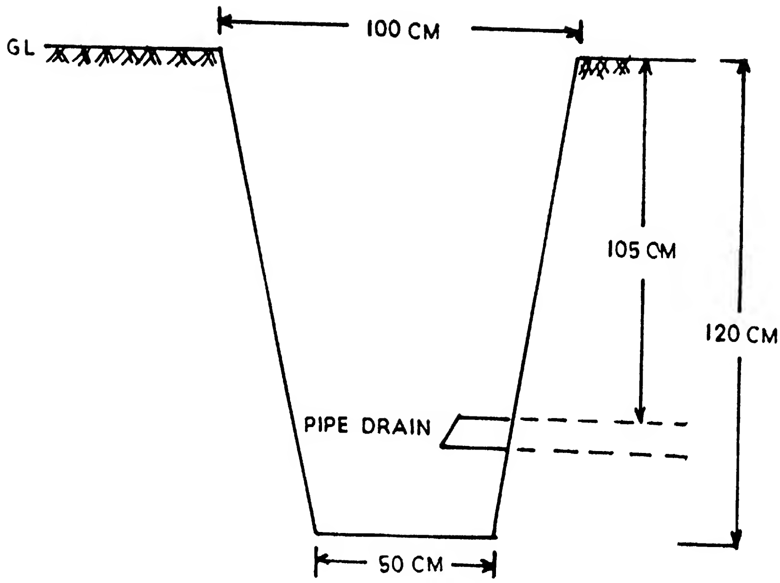


Fig. 1B Cross-section of a collector drain showing the protruding lateral pipe drain

DESIGN OF PIPE DRAIN SYSTEM

Before installation of pipe drainage system in a particular area, information on the following aspects need to be collected :

a) Topographical survey of the proposed area and identification of major and minor ridges and depressions of the land.

b) Outlet availability.

c) Data on extent, frequency and seasonal flood and highest and average water levels at the recepient river/stream.

d) Soil survey for physical properties.

e) Availability of pipe materials, filter and envelope materials.

The design of the system will require consideration of the following points:

1. **Drain depth**

The drain depth is mainly dependent on the availability of the outlet and root depth of the crop. The depth of the lateral drain or field drain should be sufficient to adequately drain the sub-soil water from the root zone of tea. The effective root depth of tea is considered to be 90 cm from the surface and therefore to control the water table below this depth the average depth of the lateral drains should be minimum of 105 cm. The depth of the sub-main drain and main drain should not be less than120 cm and 150 cm respectively.

2. **Drain spacing**

The drain spacing is effected by hydraulic conductivity, amount of water to be drained out and the effective root depth of plant.

Installation of a single drain in the field exerts its influence on the water table and lowers it down to the depth of the drain bed near its immediate vicinity. The field of influence will radiate on both the sides of the drain to some distance. As the distance between the drain increases the water table is controlled at a shallower depth. This has been illustrated in Fig. 2. When a single drain P1 is installed then the water is controlled to the depth of the drain bed at its immediate vicinity and the draw down curves are represented by DW1 lines. The water table at point A and B will be controlled at d1 depth from the surface. When P2 and P3 drains are installed the draw down lines of the drains will intercept at the mid point between the drains and the draw down curves can be represented by DW2 lines. In this situation, the water table at points A and B will be controlled at depth d2 from the ground surface. If the drains can be installed at deeper depth like Pi1, Pi2 and Pi3 then the draw down lines should be similar to DW3 lines. The controll of water table will still be effected at deeper depth indicated by d3 as shown in the figure. (Fig. 2).

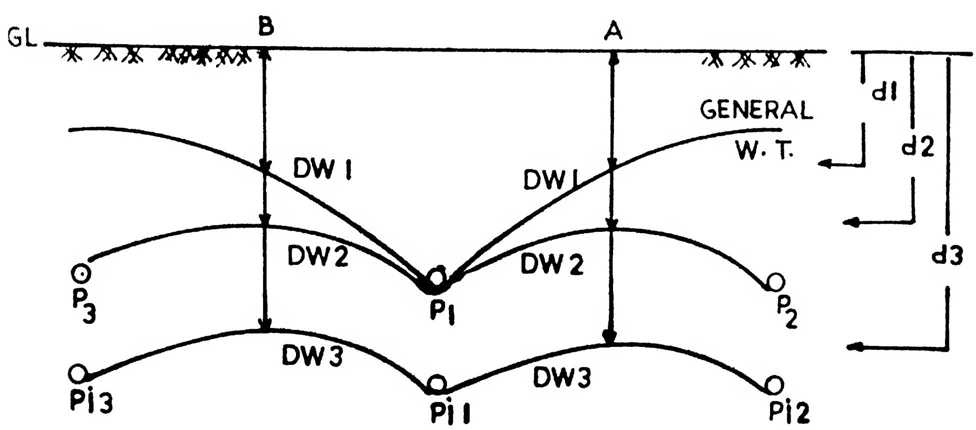


Fig. 2. Relation between drain and draw down line of water table

This principle is used in placing the drains to control the water table in the field.

There are many equations for determining the drain spacing. Out of these the Hooghoudt's steady state equation is most commonly used in tea. The equation is :

$$S^2 = \frac{4K\,Hm}{q}\,(2De + Hm)$$

where
S = drain spacing, m
K = Hydraulic condictivity of soil, m/day
Hm = Height of water table at mid-point between the two drains above the bed level of the drain, m
q = drainage co-efficient, m/day
De = equivalent depth of the impervious layer below the drain bed level, m.

The De depends on the drain spacing and the depth of impervious layer from the surface. The equation is represented diagrametically in Fig. 3.

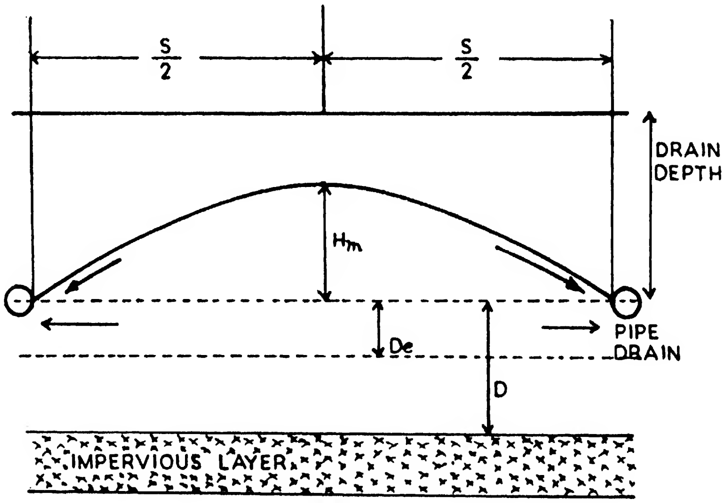


Fig. 3. Diagramatic representation of Hooghoudt's equation

The hydraulic conductivity and the drainage co-efficient estimated for some regions of N.E. India are given in Table 1 and 2 respectively.

Table 1 :Range of hydraulic conductivity for different soil types

Soil types	Permeability m/day
Loamy sand	2 - 5
Sandy loam	0.85 - 1.50
Loam	0.50 - 0.75
Silt loam	0.30 - 0.50

Table 2 : Estimated values of Drainage co-efficient for different regions

Zone	Drainage co-efficient mm/day
Middle and lower Assam	7- 8
North Bank and Upper Assam	8-10
Dooars	10-15
Terai	8-10
Darjeeling	6- 7
Cachar	8-10

3. **Relationship between drain depth and spacing**

There is a definite relation between the drain depth and spacing. More the depth of drain wider is the spacing and vice versa. In an area where depth of drain is restricted either by inadequate outfall or by presence of impervious layer at a shallow depth, water table can be controlled by putting shallow drains at frequent interval. This relationship has been shown in Fig. 4.

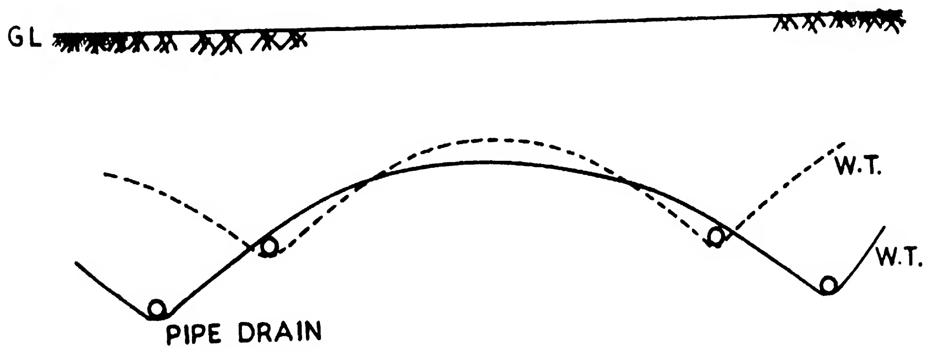


Fig. 4. Relation between drain depth and spacing

4. **Drain size**

In pipe drain system the capacity of the pipe to drain the water is to be determined. This is determined by Manning's formula i.e.

$$Q = DC \times A = \frac{V \times a}{100}$$

$$V = Km\, R^{0.667}\, S^{0.52}$$

where :

DC = Drainage co-efficient, m/sec

A = drainage area, m^2

V = velocity of flow in the drain, cm/sec.

a = cross-sectional area of the pipe drain m^2

Km = Manning's co-efficient,

Km = 38.4 for corrugated PVC pipes

= 51.7 for tile and rigid PVC pipe.

R = hydraulic radius = $\frac{a}{p} = \frac{d}{4}$

d = diameter of pipe drain, cm

S = hydraulic slope, m/m

Q = design flow rate, cum/sec.

In tea 100 mm is the minimum size recommended, but 125 and 150 mm are commonly used sizes under normal conditions.

5. **Drain bed grade**

To make the pipe self cleaning it is necessary to provide a designed grade in the pipes. The most desirable working grade is considered to be 0.20%. This is based on a minimum velocity of about 45 cm/sec at full flow of the pipe. If the grade is more than the designed rate there is possibility of blowing out of the pipe drain specially at the discharge end.

6. **Filter and envelope material**

Filter or envelope material is one of the important components of the design of the pipe drain system. Certain materials with high resistance against decomposition and with high porosity and infiltration rates are used around the pipe drain. Normally gravel, nilon cloth and plastic slips are used as filler materials. In our experiments only gravels and nylon cloth were being tried. These filter and envelope materials are used in pipe drain system for the following purposes.

(a) This primarily works as the filter material of the pipe. It should permit the fine clay and silt particles to move through the envelope material to inside the pipe and the flow should be such that it will not allow these particles to settle inside the pipe. But it should retain the bigger sand particles which may otherwise clog the holes of the pipe or find its way to the pipe. The designed velocity of flow may not remove these bigger particles and as a result siltation will occur inside the pipe.

(b) Water conveyance and permeability of the filter material also helps in conveying the water quickly into the drain. This is because of the fact that filter materials work as a porous strata inside the soil profile. In addition, it increases the area of permeable layer around the drain.

(c) Filter materials work as bed cushion and improve bedding condition of drain. This provides, in addition, some elasticity to the pipe against the possible change of soil strata. To find out the size of the gravels the following equations are used:

For graded material: $$\frac{D50\ \text{Filter}}{D50\ \text{Base}} = 12 \text{ to } 58$$

OR

$$\frac{D15\ \text{Filter}}{D15\ \text{Base}} = 12 \text{ to } 40$$

For uniform material: $$\frac{D50\ \text{Filter}}{D50\ \text{Base}} = 5 \text{ to } 10$$

OR

$$\frac{D15\ \text{Filter}}{D15\ \text{Base}} = 5$$

7. Drain Materials

The materials that can be used as pipes should have the following desirable qualities:

a) Resistance to bio-chemical changes and weathering

b) Sufficient strength to bear load under field condition

c) Low water adsorption

d) Less prone to cracks and damage

e) Uniform wall thickness

The most common materials are clay, concrete and plastic or PVC tubes.

(1) **Clay pipes (Tiles)**

These tiles are made of shale, fire clay or surface clay. They are mostly 30 cm long. The diameter varies from 10 cm to 20 cm. Some tiles have collar in one end to be fitted with the plain end of the other. Tiles with 12.5 cm diameter without collars are mostly used in tea. These are laid in the drain bed keeping 3 mm gap between them for entry of water.

(2) **Concrete tiles**

These are made of portland cement or concrete and cement. These are made when clay tiles are not available or when tiles of bigger diameter are required. However, they deteriorate quickly under acid soils.

(3) **Plastic pipes**

The PVC pipes are most commonly used. They are of two types (a) rigid and (b) corrugated. The rigid pipes are normally 10 cm in diameter and 3 m long. They have four lines of saw-slits mostly longitudinally and sometimes transversely. The corrugated pipes are found in roll and have many small openings in the valley of the corrugation. There are generally three different sizes of these pipes viz 90 mm, 110 mm and 125 mm diameter with 2 mm, 2.2 mm and 2.5 mm wall thickness respectively. The dimensions of the perforations are 25 mm long and 0.6 to 0.8 mm wide. There are 40 slites per metre length of pipe in 4 rows making a total inflow area of approximately 600 mm.

DRAIN INSTALLATION

The installation of pipes in the field is a very important operation in planning and designing a pipe drain system.

A faulty installation, instead of draining the area, will rather cause acute waterlogging problem. Unlike the open drainage system allocation of zone of fault is difficult in pipe drain system and it involves considerable expenditure in correcting them.

(1) **Digging trench**

A trench is dug to the desired depth by manual labourers using hand tools for installing the pipes. The trench may be 60 cm wide at top and 20 cm at bottom. The side slope is given only for convenience of digging drains.

(2) **Drain bed grade**

The drain bed grade should be set up by string-line method by using level survey tools. This is to be rechecked after the filter is placed on trench bed.

(3) **Blinding of drains**

The blinding is accomplished by placing the designed filter material around the pipe. The minimum thickness of blinding should be minimum 7.5 cm all around the pipe drain.

(4) Pipe laying

The drain should be laid from the top end towards down side. When tiles with collars are used they should be properly coupled and the collars should be flushed with the bed. The rigid PVC pipes have collars in one end. In case of corrugated pipes sockets are available for making the joints.

(5) Filling of trench

At the time of digging the trench, the top and sub soil should be seperately heaped. A layer of 15 cm to 30 cm top soil should first be placed on the envelope material which has covered the already laid out pipe. Thereafter, the trench should be filled up in the same manner as was dug out to maintain the original sequences of the soil layers as far as will be possible. Some extra soil should be heaped on the drain line to allow for the settlement in the trench. A vertical section of a filled in trench has been shown in Fig. 5.

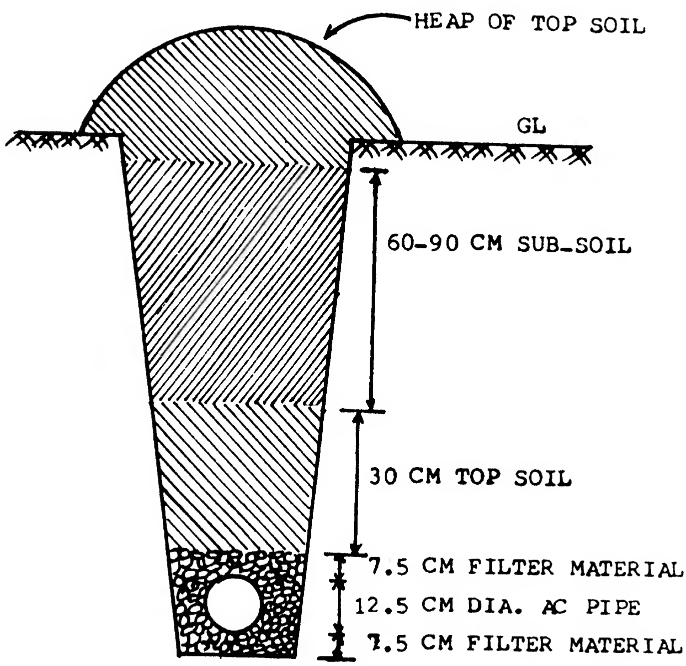


Fig. 5. Blinding the pipe drain

OTHER ACCESSORIES OF PIPE DRAIN SYSTEM

1. Surface inlet at depressions

To remove the water from depressions and to reduce the run-off in a pipe drained area a vertical structure is used. This is known as inlet. It is made of tiles or PVC pipe pieces placed vertically from the center of depression to the underground pipe drain. The top end is covered with an iron plate having

perforations over which a heap of graded gravel is placed. The downward end is fitted to the drain. The water in the depression will pass through the filter material i.e. the heap of the gravel and reach the pipe drain. The inlet structure has been shown in Fig. 6.

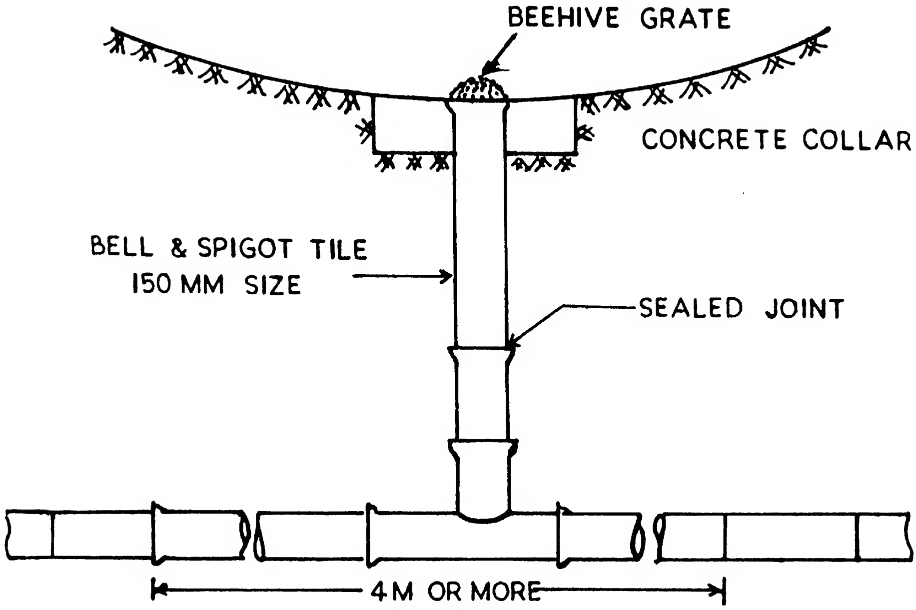


Fig. 6. Surface inlet for pipe drain

2. **Blind Inlet**

When the quantity of water at the surface which is to be dealt with is less and the water in that area contains more sediments then a blind inlet as shown in Fig.7 may be used. It is a pit dug in soil to the drain depth. It is refilled with stones, gravel and coarse and fine sand layerwise (15 cm - 20cm) upward from coarse to fine grade.

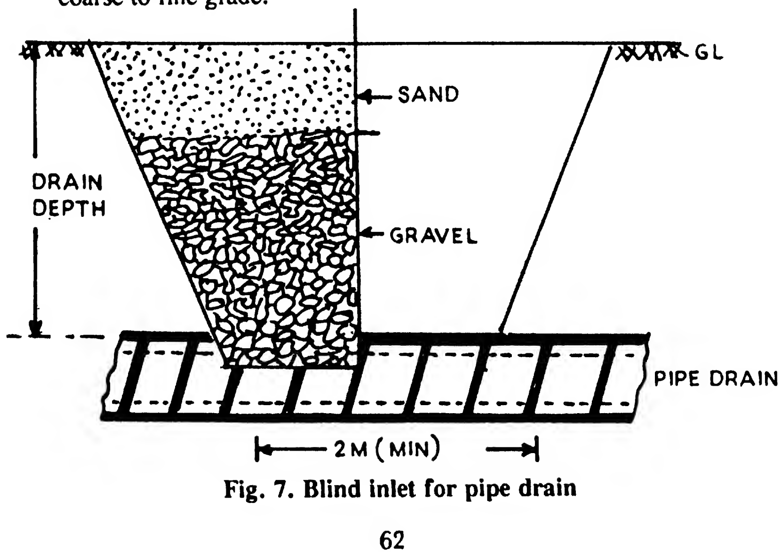


Fig. 7. Blind inlet for pipe drain

3. Sedimentation basin

When the soil contains large quantity of fine sand and is comparatively loosely packed there are chances of fine sand passing into the pipe drain. In such condition, some junction boxes or sedimentation basins are constructed by brick and cement below the ground in the drain line. It extends upto soil surface and is covered. A portion of pipe drain discharges the water into this basin and the sediments get deposited at the bottom. Water can pass into the next portion of drain easily from the basin and the rate of flow is maintained. The deposited sand and silt may be removed by opening the cover of the basin at the ground surface. The depth of the basin should be higher than the drain depth. A sedimentation basin is shown in Fig. 8.

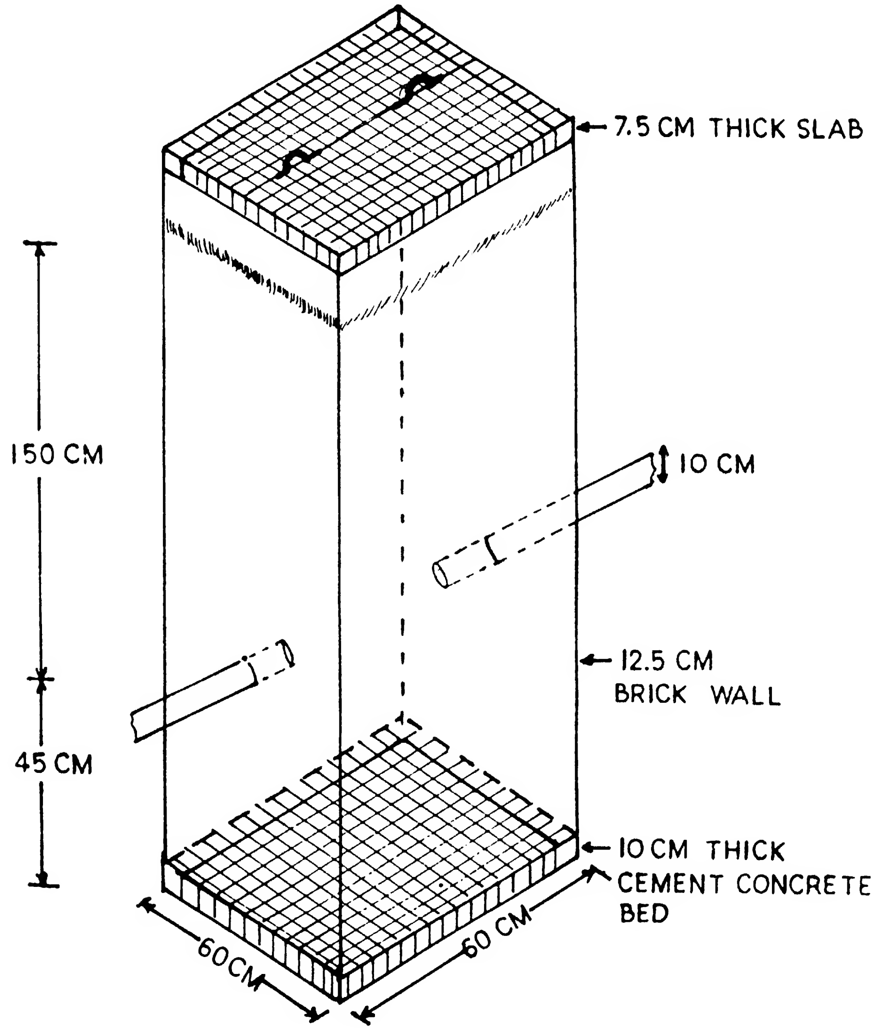


Fig. 8. Sedimentation basin for pipe drain

4. **Relief pipes and breathers**

Relief pipes and breathers are small size vertical risers like the inlet, extending from the pipe drain to the surface. These are installed on long drain line to prevent the development of vaccum, damage to pipe line or blow-out of drains. These are not common when the grade of drain is not higher than 1%.

COST OF PIPE DRAIN SYSTEM

The cost of pipe drain system is bound to be higher than the open drain system. The cost of installing under ground pipe drain system using two different pipe materials has been evaluated and compared with an equivalent open drain system and the data are given in Table 3. The cost of installation of the corrugated pipe is comparatively lower than installing A.C. tiles. However, while mentioning the cost of open drainage system cost of culverts has not been included.

Table 3: Estimated cost for installing pipe drain (Rs./ha)*

Drain material	Drain dia mm	Drain spacing m 24	30	35	48
A.C. pipes (300mm long)	125	21,000	16,800	14,400	10,500
PVC corrugated (per forated)	100	17,000	13,700	11,700	8,500
Open drains**		2,100	1,700	1,500	1,100

* Cost include material, filter earth work & installation and back filling.

** Cost of culverts not included

Though the initial cost of pipe drain system is high the maintenance cost of underground pipe drain is negligible as compared to the high maintenance cost of open drain system. The life of the pipe drain system is expected to be more than 50 years. Thus, after some years the cost of maintenance of pipe drain will be very minimal.

FUTURE OF PIPE DRAIN SYSTEM

Considering the shortage of labour at the peak of the season for drain maintenance work, high cost of maintenance of open drain system and possibility of use of machineries in tea field in near future, it can be said that adoption of pipe drain system, in a phased manner in problem areas will be a good proposition. However, it should be kept in mind that installation of pipe, filter material, backfilling etc. require experienced and scientifically skilled personnels.

DESIGNING DRAINAGE SYSTEM FOR DARJEELING HILL SLOPES AND CACHAR TEELAS

P.K. BORDOLOI & H. GOSWAMI

INTRODUCTION

The physiographic and climatic conditions of Cachar & Darjeeling tea areas are totally different from those prevailing in other tea growing areas of North East India. Problems relating to Soil and Water Management are also different and call for special type of Soil and Water Management pratices in these two areas.

Topography

Tea plantations in Darjeeling are situated on hilly slopes, whereas, the tea areas of Cachar includes teelas, plateaus and bheels. Tea plantations in areas with more than 50% slope is very much common in Cachar and Darjeelings. In Chachar about 40% of the total tea areas is on teela slopes.

Rainfall

Darjeeling comprises of several valleys. The intensity and distribution of rainfall varies considerably from valley to valley. It varies from as low as 2500 mm to as high as 4100 mm with an average of about 3000 mm / year. Rain storms of intensity as high as 100 mm in an hour, 270 mm in 6 hours, 650 mm in 48 hours and 1000 mm in 5 continuous days has also been received at our meteorological observatory. In Cachar also the average rainfall is 3000 mm per year and storm of high intensity such as 100 mm/hr. is not uncommon. The data analysis futher indicates that about 96% of the total annual rainfall is received during the period April to October (7 months).

Soil

In Cachar teelas soils of sandy loam and loam types are predominant. Loamy sand and Silt loam are also present in some teelas. Soils of Darjeeling hill slopes belong to fine to medium texture. The typical Darjeeling soils are chocolate coloured loam and silt loam type.

Soil Erosion

Steep slope, unfavourable soil texture, presence of stony layers below the ground create serious erosion problems in Darjeeling and Cachar tea areas. Improper watershed management, overgrazing, large scale deforestation have made the soil management problem very difficult. Land slide and sinking have also been a serious problems of these regions. It has been estimated from available records that in the last 100 years, more than 300mm of fertile top soil has been lost through soil erosion by water in Darjeeling.

Soil Conservation Measures

It is observed that in Darjeeling in most of the areas tea is planted on terraces having narrow base levels. More often than not the vertical sides of the terraces are reinforced with stone works/retention walls against erosion. The terraces are being used for soil conservation work, but they are difficult to design, expensive to maintain and consume 25 to 30% of effective land which otherwise could have been planted with tea. For these reasons, terracing does not appear to be a practical solution of tea areas of hilly slope. If given a choice, the tea estates would probably like to level of the old terraces for making more room for tea. This, hence is not an ideal approach, as it would further aggravate the soil erosion problem if adequate care is not taken.

It has been established that a well managed row crop like tea with full ground cover provides adequate protection to soil in respect of erosion and moisture conservation. However, in hilly areas like Darjeeling and Cachar, a well designed drainage system is a must for safe disposal of excess run off and thereby control of soil erosion effectively. This is required even if there is a complete ground cover by tea.

Following soil conservation measures are commonly suggested

1. Practice of minimum tillage and soil disturbance.

2. Contour planting of tea.

3. Adequate mulching of newly planted young tea.

4. Partial chemical weed control on strips across the slope.

5. Adequate cover of deeprooted grasses on vacant patches.

6. Immediate infilling followed by heavy mulching in freshly levelled terraces.

7. Retention of pruning litter in situ.

8. Installation of a well designed 30-45 cm deep, 30 cm wide run off drainage system spaced at 10-15 m across the general direction of the slope.

9. Providing interceptor drains at suitable places to cut off seepage water from high lands.

10. Use of soil conditioner to improve soil structure.

11. Stabilizing drain banks and beds by growing suitable vegetation.

12. Construction of well designed structure for controlling gully erosion.

13. Development of well covered artificial waterways for safe disposal of surface run off.

14. Construction of well designed soil conservation structures at places where the soil is relatively more unstable.

For achieving desired results, it will be necessary to follow any one or a combination of more techniques mentioned above. It is expected that adequate soil conservation measures in Darjeeling and Cachar teela slopes will help conservation of valuable top soil for sustained increased yield of tea.

Drainage

The influence of high intensity rainfall, steep slope and underlying rocky strata results in drainage problems of special nature. Though the coarse textured soil have high permeability, because of its shallow profiles, these soils get saturated early and thus reduce infiltration intake. These soils often develop structureless layers at some depth rendering the natural drainage of the sub-soil difficult.

The seepage flow at shallow depth causes serious waterlogging in the root zone that decays tea roots and restricts the uptake of essential nutrients required for optimum growth of tea. The seepage flow under hydrostatic pressure causes landslide and land sinking problems at places.

In Cachar, waterlogging in teela areas although is not a common problem, under the following circumstances, waterlogging in teelas could be a serious problem :

1. At places where there is abrupt change of slope.

2. At places where impervious layer exists at shallow depth.

In respect of waterlogging, the flat areas pose different problem. Generally the flats are low lying areas surrounded by teelas and rainfall and seepage from the teelas is principal source of excess water causing waterlogged conditions .

The problem is aggravated due to the following reasons :

1. Inadequate depth and size of interceptor drains at the base of the teelas.

2. Wrong alignment of the drainage system.

3. Wrong placement of interceptor drains.

4. Restricton of outfall of different magnitude.

NEEDS FOR A SCIENTIFIC APPROACH ON DRAINAGE :

A drainage system should be designed with the following objective in mind:

1. To check soil erosion

2. To regulate soil moisture

3. To ensure safe disposal of runoff water

4. To intercept seepage inflow and thus control the water table at desired depth.

It is found that the first three needs are of most universal nature and a solution for them is required by most of the estates. The seepage inflow is a problem in some locations as for example, the Cachar flats and teelas and Darjeeling slopes.

It is an established fact that closely spaced graded contour drains can adequately contain soil erosion problem as well as regulate soil moisture to the best possible way. The horizontal distance, vertical intervals and their dimensions are available in Tocklai Memorandum No.28. It is needless to say that there can not be any alternative but to adopt this system as effectively as possible in tea estates located in hill slopes and undulating areas.

While laying out such a system, maximum attention is necessary on location of collector and the junction part of the field drains with them. A faulty drain junction forms gullies and results in more erosion than preventing it.

Investigations have shown occurence and fluctuation of water table at shallower depths, between 20-90 cm, below the ground level, during the period June to September even in the hills. It was also found that the rainfall received locally had very little or no effect at all on water table in such areas. This confirms the fact that the local rainfall is not the major source of excess water contributing to the water table. It is rather the sub-surface seepage flow from the adjacent high land which is causing the water table to rise. The degree of rise and fall of water table mainly depends upon the quantum and rate of seeepage flow and the soil properties.

It has been observed that on sloping lands, ground water normally flows through the pervious upper layer underlying an impervious base. This ground water flow, often called interflow, causes waterlogging at certain sites :

1. Where the slope of the land changes from steep to flat, (1A).

2. Where impervious layer exists at shallow depth, (1B).

3. Where ground water may rise to the surface at the foot of a slope (1C).

4. At the confluence points of pervious top layer and poorly pervious sub soil layers out cropping along sides of slope (Fig. 1D).

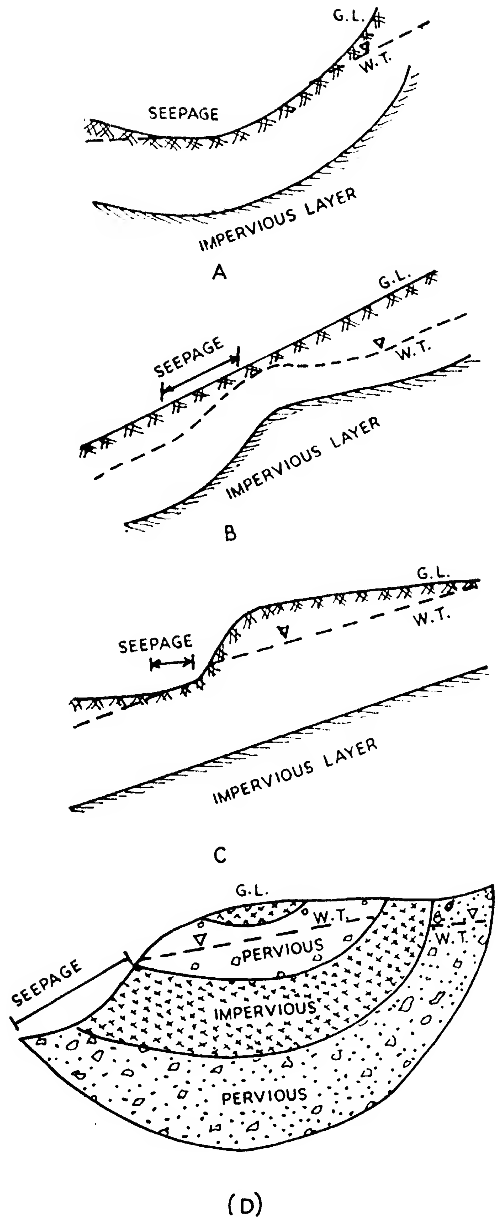


Fig. 1A, 1B 1C & 1D

Under these conditions, an interceptor drain is required to control the water table. These drains can also be provided at random or in parallel depending upon the situation. However, the objective remains that the interceptor drain should be placed up to the impervious layer for intercepting the maximum amount of seepage flow. Such drains could be open or burried type and there is no specific spacing for these drains. Quantum of seepage flow and studies of soil profile can only dictate the number of such drains to be provided.

Field Investigations

The following field investigations are required for installation of interceptor drainage system :

1. Nature and extent of the waterlogged area from topographic survey.

2. Nature (phreatic, artisian) and direction of ground water flow.

3. Soil profile characteristics.

4. Water table and hydraulic head measurements.

5. Depth to the impervious layer.

LOCATION OF DRAINS

The location of interceptor drains considered as most appropriate in the following kind of situations quite commonly encountered in the hills :

1. Abrupt change in topography

2. More permeable soil layer sandwiched between poorly pervious layers.

3. Impervious layer close to ground.

4. Permeable strata under hydrostatic pressures.

In conclusions, it may be said that soil and water management in slopy lands should be viewed with utmost concern. Wrongly designed drainage system in flat lands may delimit the productivity of the crop to certain extent, whereas, an ineffective drainage system in slopy lands is bound to lead to severe land loss and disaster.

In Darjeeling, experiments were conducted during 1983-84 in areas where water table was fluctuating between 30 and 43 cm depth below ground level throughout the year. A systematically designed interceptor drainage system could effectively control the water table below the root zone of tea.
The results from several experiments conducted in Darjeeling hill slopes indicated that the productivity of mature tea can be increased by minimum of 15% provided other tea management practices are maintained at optimum level.

PLANNING OF DRAINAGE FOR SAFE DISPOSAL OF RUNOFF WATER AND EROSION CONTROL IN SLOPY LAND

J.CHAKRAVARTEE and N. BORPUJARI

INTRODUCTION

For optimum growth of plant,unrestricted supply of both air (oxygen) and water in the root zone is essential.Such a condition is generally maintained at field capacity moisture level,when both air and water in the root zone remain in an optimum balance.

Objectives of drainage in slopy areas :

The main objectives of drainage in slopy areas are :

1. Protection of the soil from erosion, by reducing velocity and area of flow,
2. To conserve soil moisture,
3. To control subsurface runoff and lowering of water table,
4. To remove excess moisture from the root zone.

When rainfall occurs on a dry soil which is well below the field capacity say during the period of February-March,except under exceptional condition,nearly all the water infiltrates into the soil.Thereafter,gradually the soil reaches the field capacity.

Once the soil reaches the field capacity, the rate of infiltration slows down and is dependent on the percolation capacity of the soil.On the other hand,the rate of percolation is governed by soil types. Finer the texture slower is the percolation.

During the monsoon, usually rainfall exceeds the percolation capacity of soil and under this condition runoff occurs.The runoff particularly following a storm of high intensity erodes the soil.

Degree of soil erosion varies with the intensity of rain,slope of land,soil type,vegetative cover and volume of runoff over the soil surface.

The runoff water flows over the soil surface at right angle to the contours and finds its way to natural depressions and waterways which eventually leads to streams, rivers and finally to the sea.

FATE OF WATER INSIDE THE SOIL

i) The water that infiltrates into the soil is first held by soil against the force of gravity.

ii) The excess water percolates vertically downward until it reaches the wa... table and this contributes to the rise of the water table.

iii) The horizontal movement (lateral movement) of ground water is slow, bu... nevertheless, follows the same direction as the runoff water i.e. at rig... angle to the contour lines.

Infact the catchment planning is based on the principle of movement of water, (both runoff and ground water).

Water movment in the soil is shown below diagramatically.

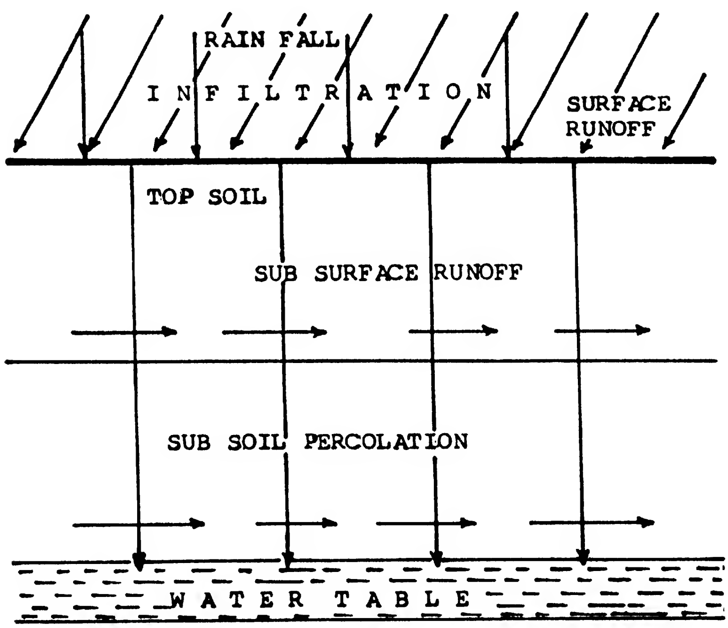


Fig. 1 : Water movement in the soil

DRAINAGE PLANNING

Annual rainfall in the tea growing areas of N.E. India varies between 1500 mm and 4000 mm and 70-80% of the total quantity is received within a short spell of 5-6 months (May to October). 50-60% of the rainfall occurs at intensities of sufficient magnitude to cause soil erosion. Therefore, the plan for a good drainage system must provide :

1. Adequate protection from soil erosion and conservation of soil moisture.

2. The plan must incorporate a network of drainage system that ensures safe and satisfactory disposal of water and lowers the watertable where required.

3. A satisfactory main outlet (main drain) is essential for without it, the entire network of drainage, however perfectly laid out, will be of little use. The main drain must be large enough to carry away the excess water from the catchment area. Its dimension depends largely on the size of the catchment area to be drained, rainfall, soil type, outfall, etc.,

4. The plan must provide complete plucking access, supervision, vehicle movement etc.

Therefore, to achieve the above objective, a careful advance topographical planning on catchment basis is essential.

For drawing up a catchment plan and drainage, the following pre-requisites are important :

1. Information on topography.

2. Information on soil type, permeability, rainfall and slope.

3. Information on water table

4. Information on highest flood level

5. Information on outfall

CATCHMENT PLANNING :

In catchment planning,it is essential that water must be conserved and also disposed off safely without causing soil erosion.As the surface runoff and ground water flow at right angle to the contour,the topography must be the over- riding factor in the disposal of both runoff and ground water.

As a prerequisite to catchment planning,it is essential to mark all the topographical features like major/minor ridges,natural depressions and waterways on the level survey map.The objective is to divide the whole estate into **Major or Natural catchments** which is followed by further sub division into **Minor** or Natural catchments.Subsequently these Minor catchments are again sub divided into man made constructions such as roads,paths and graded contour drains so that each unit becomes a catchment.Finally further division is undertaken by contour planting.

The elevation of each contour lines is mentioned in the map to show the degree of rise and fall of the land and where the contour lines are **convex** to the fall,then the movement of water over such area will be away from the apex of the curve.Where contour lines are **concave** to the fall,then water will collect in the apex of the curve and follow downhill in a line connecting each apex.Following this principle,ridges and dperessions can be marked out on the map easily.In this way all the catchment areas can be identified on the map accordingly.

For understanding the plan, it is essential to acquaint with following terms which are used commonly.

Contour line

A contour line is an imaginary line which joins the points of equal heights on earth's surface. These lines are drawn on topographical map connecting all those points on ground which are at the same distance above or below a specific datum,usually the mean sea level.

Contour interval

This is the vertical distance between two contour lines and is inversely proportional to slope.Therefore,on steep slope the contour lines are closely spaced.When the slope is uniform,the contour lines are placed evenly and on flat land,the contour lines are straight and parallel.

Contour lines are level lines and, therefore, they are always perpendicular to the lines on steepest slope. Contour lines cannot merge or cross one another except in case of overhanging cliffs and they must close upon themselves either within or outside the borders of the map.

Movement of water

The movement of water over the soil surface follows the laws of gravity i.e. it flows down at right angle to the contours. Where the contour lines are convex to the fall,then water will flow away from the apex of the curve. In case the contour lines are concave to the fall, water will collect at the apex of the curve and will move away in a line connecting each apex. Natural catchments are build up on the basis of this simple principle.

Water Management

i) **Conservation**

Water conservation is of utmost importance in areas where drought is a regular feature.In such area rain water should be conserved by constructing suitable physical structure like dams,embankments etc.,

ii) **Disposal**

Disposal of excess rainfall,which may runoff after a heavy storm,into natural and artificially constructed waterways is important. The banks of such waterways should be stabilized by growing suitable vegetation or constructing stone/masonry works.

iii) **Soil Conservation**

Safe disposal of excess rainfall should be coupled with good soil conservation measures.Such measures should include construction of graded contour drains,physical barriers across the slope,stepped drain beds at intervals,small dams and retaining walls etc. It is essential that adequate vertical intervals should be provided between the graded contour drains and this will depend upon :

Percentage slope
Soil Type
Rainfall

To calculate the vertical intervals between the graded contour drains for medium textured soil,the following formulae can be used:

i) Rainfall below 2500 mm,
vertical interval in meters (V.I) $= \left(\dfrac{\text{Percentage slope}}{4} + 3\right) \times 0.3054$

ii) Rainfall below 2500 -4400 mm
vertical interval in meters (V.I) $= \left(\dfrac{\text{Percentage slope}}{4} + 2\right) \times 0.3054$

iii) Rainfall above 4400 mm, veartical
interval in meters (V.I) $= \left(\dfrac{\text{Percentage slope}}{4} + 1.75\right) \times 0.3054$

These formulae are also applicable to other types of soils with some adjustments as follows :

<u>Soil Type</u>	<u>% of adjustment to be made</u>
i) Coarse texture (sands and sandy loam)	: + 12 to + 20%
ii) Moderately coarse texture (sandy loam)	: + 4 to + 12%
iii) Medium texture (loam and silt loam)	: + 4 to -- 4%
iv) Moderately fine texture (silt loam and silty clay loam)	: -- 4 to -- 12%
v) Fine texture (silty clay and clay)	: -- 12 to -- 20%

A gradient of 0.20% (i.e. 20 cm per 100 m length) is generally recommended for these drains.

The above formulae are applicable mostly in area where the slope is very high and soil erosion is the main problem i.e. where the slope exceeds 3%. Therefore, these formulae will not be suitable in flat areas with slope less than 3%. For such areas instead of the vertical intervals, the horizontal distance between the field lateral drains is important

Marking of graded contour drains on map

Since the contour lines represent the elevation of the points they are passing through,it is easy to calculate and mark the graded contour drains on the topographical map for implementation in the field later.

CONTOUR PLANTING

In hilly/slopy land, it is necessary to further divide the drain catchment into row catchment by planting along the contour. Planting exactly on the contour will result in the distance between hedges varying due to irregularities of the topography, This is undesirable. This problem is overcome by adopting a system called the **MASTER ROW PRINCIPLE** where some of the irregularities are taken care of.In this method the Master Row is located on the ground between two pairs of contour drains and the tea rows are aligned parallel to the Master Row.The method is based on the following principles :

i) If a pair of graded contour drains converge in their direction of flow,the Master Row is made parallel to the top or higher contour drain.

ii) If a pair of graded contour drains diverge in their direction of flow,the Master is made parallel to the bottom or lower contour drain.

Any of the two methods given below can be used for marking the Master Row.

METHOD 1

Requirements

Leader	- One
Assistant	- Three
Coir string	- Two pieces long
Bamboo stakes	- Sufficient nummbers

i) The two assistants tie one end of each piece of coir string round their waist and one goes to the starting point of the upper contour drain and the other to the starting point of the lower contour drain. The leader positions himself at a point near the top contour drain, which is one third of the total distance between the contour drains and holds the two pieces of the coir strings,one end on each hand,and the loose ends trailing behind him.The third assistant stands behind the leader with a supply of stakes with him.

ii) The leader and the two assistant with coir string bound around their waist walk along their respective contour drains keeping the string at right angle to the drains all the time.The leader holds the two pieces of the string taut infront of his chest and start walking together towards the water course.As they walk,the leader can feel whether the drains are converging or diverging.

iii) If the leader's hands are pulled apart then the drains are diversing and therefore,the Master Row should be parallel to the lower contour drain.He therefore,pay out string to the assistant on the upper side and keeps the string taut on the lower side and continues walking together until he fills his hand coming together and at this point the drains are conversing.Now he keeps the strings on the upper side taut and takes in the string from the lower side.

iv) The third assistant follows the leader and drives the stakes on the foot prints of the leader thus marking the Master Row.

v) The team in this way covers the whole length of the catchments between each pairs of contour drains from crest to the water course marking the Master Row for each drain catchment.It is important to note that the leader and his two assistants should arrive the water course at the same time.

METHOD 2

Requirements

Person	- Four Nos.
Bamboo stakest	- Sufficient Nos.
Tape (33m) or Coir string	- One

i) Two persons position themselves at the starting points of both upper and lower contour drains and holds the tap or the string between them.The remaining two persons follow the first carrying a supply of stakes.

ii) Together they walk along the contour drains towards the water course noting whether they diversing or conversing.At points of maximum convergence or divergence,the follower then drives stakes on these critical points.

iii) For pegging the Master Row,one person will then position himself with the tap or string on the crest at a distance equal to one third of the distance between the maximum point of convergence from the upper contour drain.The other person will hold the other portion of the tap or string and will go to the upper contour drain if the drains are converging or to the lower contour drain,if the drains are diverging.One person stands behind the first with a supply of stakes.

iv) The two persons holding the tap or the string taut walk together and the third person drives the stakes on the foot prints of the person walking in between the contour drains until the first point of convergence is reached.At this point the person at the middle stands fast and the other person moves to the lower contour drain and continues walking towards the water course until the point of maximum divergence is reached.Here again the person walking in the middle stands fast and the other person goes to the upper drain and together they walk towards the water course,until the point of maximum convergence is again reached and the shifting of position is effected.In this way the process is repeated until the watercourse is reached. While all the third person continues to drive stakes on the footprints of the person walking on the middle marking the Master Row.

After marking the Master Rows,staking for planting should be done at the predetermined spacing with hedges running parallel to the Master Row.

IMPLEMENTATION OF THE MASTER PLAN

The master plan includes the following :

1. Soil moisture conservation
2. Soil conservation
3. Safe disposal of excess water
4. Access

The Master Plan will have to be implemented in stages as follows:

i) Ridges, sites for the roads,paths and collector drains should be marked on the ground.The topographical features of the map should be compared with that of the ground by walking over the area with the map.

ii) With the help of the topographical map and by taking measurements from the ground reference points,mark out each contour on the ground.Thereafter,grade these contour drains at a gradient of 1:500 with the help of a Dumpy level.For this purpose the entire length of the contour line is staked at every 6.09m (20') apart and spot levels are taken at every stake point and a fall of 0.0121m (0.04') is maintained between two stake points along the contour line.

This is done by setting up the Dumpy level at a suitable place and recording the first staff reading at the first starting point of the drain.The man holding the staff then moves 6.09m (20') along the contour towards the collector drain. The staff man is asked to adjust the position of the staff until a reading of 0.0121m (0.40') morethen the previous staff reading is sighted through the instrument. When the correct reading is obtained, the position of the staff is marked with a stake.

To maintain the constant distance of 6.09m (20'), a piece of string of this length is tied on the bottom of the staff and the end of the string is attached to a stake.

iii) Once the staking of each drain is complete walk down the line of stakes and adjust them to smooth out the kinks by moving **not** more than one marker in **three** and stakes should be moved uphill rather than down hill.To create extra hydraulic pressure in the drain,the first stake should be moved uphill by 0.030-0.060m(0.1-0.2') and the last stake down hill by similar distance by using Dumpy level.

Access

The importrance of all weather easy access for both men and vehicle is obvious.Though the siting of roads depends upon economic factor,they should be direct and chep to construct and maintain.Roads which follw the crests or ridges meet these requirements as they have added advantage of easy water disposal,good supervision and easy management. Therefore, all roads should be aligned to follow main crests of watersheds.If this is not possible,then for this purpose graded contour lines must be used.

Detailed plan

The detailed plan will indicate the overall policy and provide the architecture for its physical development in respect of :

i) Access

ii) Water management and safe disposal of water

iii) Soil conservation measures

The plan of catchment division showing all details for future development is called the **Master Plan.**

PRECAUTIONS

i) Sub soiling or deep ploughing should be avoided on the sites of main/sub main and collector drains.

ii) Excavated soil from the drains should be uniformly spread over the area before planting rehabilitation crop.

iii) For disposing off of only runoff water, 45-50 cm deep drains are adequate where water table never rises to within 90 cm of the ground level. For this purpose deep drains are not required.

iv) Under situation where the water table rises within 90cm of soil surface, 100-105cm deep contour drains should be dug along the graded contours.

v) Adequate mulching with suitable materials and retention of pruning litters.

PLANNING AND IMPLEMENTATION OF DRAINAGE SYSTEM IN FLAT LAND WITH RESTRICTED OUTFALL

P.K. BORDOLOI

INTRODUCTION

The quick disposal of excess water from a land through gravity discharge depends on the presence of a satisfactory field drainage system and an adequate outfall at the recipient river/stream or bheel. When this outfall is inadequate, disposal rate of excess water by gravity becomes very slow and may have even back flow during the peak monsoon months. Pump drainage becomes necessary when the difference between the elevation of tea land and the highest/average water level in the outfall is negligible.

Owing to restricted outfall, flat lands in many tea growing areas of N.E India very often suffer from waterlogging in various degrees. Rising of the bed of the main recipient river (like the Brahmaputra), due to siltation, and clogging of natural water ways due to unplanned urbanisation and also due to paddy cultivation, draining out of excess water during peak monsoon months has become more and more difficult particularly from the tea areas situated in comparatively lower elevation. Such areas demand a different approach for water movement with a proper pump drainge design system.

CATEGORISATION OF OUTFALL CONDITION

Tocklai conducted a survey on some gardens of Cachar and Assam having acute waterlogging problem and defined five categories of outfall as described below:

Category	Description
I	The difference between the average water level of the recipient river and the lowest contour of land is negative i.e. the average water level is lower than the land level (basin type). Pump drainage is required.
II	The difference does not exist or the levels are almost equal. Outfall is practically nil. Pump drainage is required.
III	The difference is equal to or less than 1m. A combination of gravity and pump discharge should be considered.
IV	The difference is equal to or less than 2m. Provision for gravity sluice gate (not for pumping) against short duration flood may be necessary.
V	The difference is greater than 2m. Drainage by gravity discharge alone is feasible.

PLANNING OF PUMP DRAINAGE SYSTEM

Planning for pump drainage requires following information:

(i) Scope of an outlet drain (disposal channel) beyond the estate boundary upto the recipient river.

(ii) Average and highest water levels on the recipient stream during the monsoon.

(iii) Assessment of the outfall restriction both in terms of magnitude and frequency. The portion of the catchment which is within 0.5 to 1.0 m above the average water level (AWL) of the river should be marked out on the topographic map showing contours at every 30 cm interval. To design pump drainage only this area is to be considered.

If the frequency of exceeding the AWL is more due to flood, than the highest flood level (HFL) should be considered for designing.

Pump drainage should be considered during critical monsoon period only when satisfactory gravity discharge cannot be effected.

DESIGNING PUMP DRAINAGE

Designing pump drainage requires consideration of the followings:

1. **Segregation of the pump drainage catchment**

   Once the area for pump drainage is correctly identified, the catchment should be isolated by providing a perimeter drain and or a bund preventing entry of water from the catchment situated on higher level into the pump catchment. While designing the outlet for pump drainage, the main channel is interrupted at the boundary between high and low areas and is diverted through a new channel to a gravity outlet. The down stream part of the channel is then used as the main drain for the area for pumping and is connected to the pumping station. Fig.1 and 2(a, b, c & d) show schematic diagrams of pump drainage catchment and how this can be segregated from the higher catchment (2a and 2b).

The existing channel may be kept as usual also but at the lower area no field drains are allowed to discharge water into this channel. New channels are dug either alongside (2c) the existing drain or at some distance from the channel (2d).

2. **Bed grade**

   Adoption of almost flat grade results in shallow depth of drain at the outlet and decreases the area for pumping. A bed grade of less than 0.05% , however, may not be exceptable in view of siltation of drain bed.

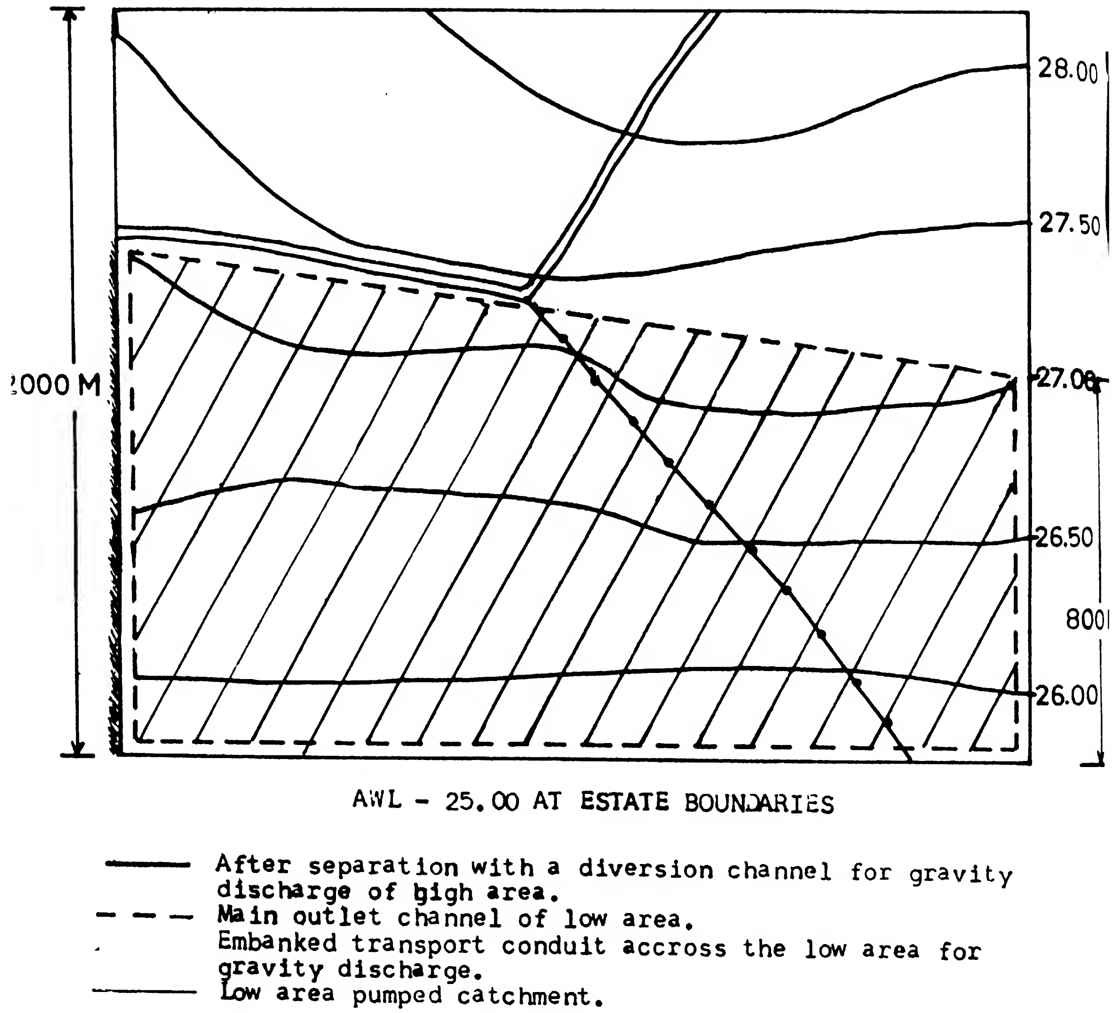
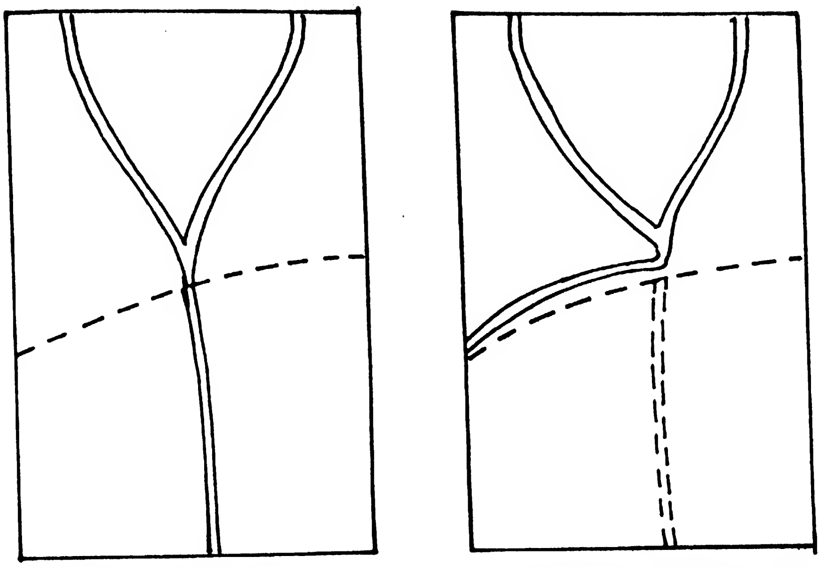


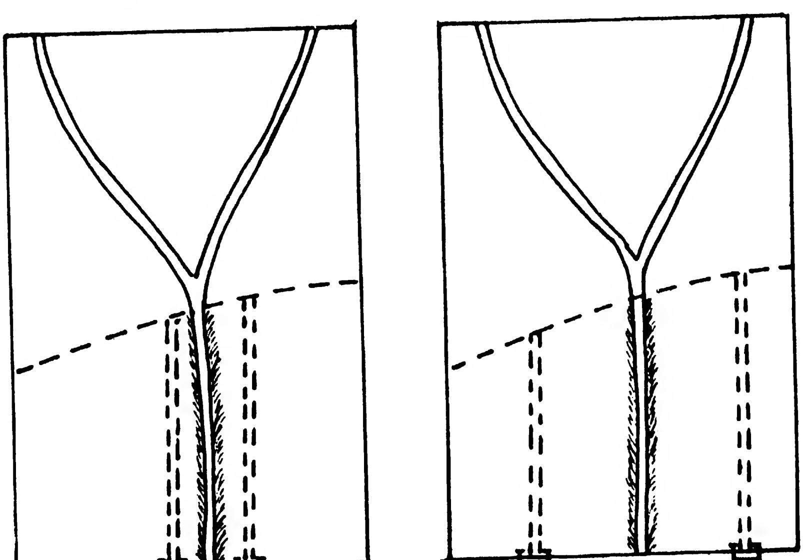
Fig. 1. Schematic diagram for a pumped area.



a. ORIGINAL SITUATION

b. DIVERSION CHANNEL FOR GRAVITY DISCHARGE

Fig. 2 (a,b): Separation of a catchment into a pumped and gravity out flow compartment



c. Embanked transport conduit accross the low area for gravity discharge

d. Pumped channels in different location

Fig.2(c,d): Separate main drains in pumped area for pumped discharge

Let us consider an area with 1500 m length of the main drain to the outlet point. The land is sloping towards the outlet. The highest contour is 30.50m. A free board of 1.2 m depth in drain is considered. Suppose the AWL is 28.70 m. Now if we put a small grade like 0.04%, for 1500 m the drop will be 0.60 m leaving a free board of 1.2 m (30.50 - 1.20 = 29.30 - 28.70 = 0.60). With 1.2 m free board we shall cover 1500 m length of the drain and reach the outlet point. The drain bed will not be below AWL. The gravity discharge from the farmost point is possible. However, this grade may lead to siltation and control of water table in the field at desired depth may not be possible. If a higher grade like 0.1% is selected the drop of 0.6 m is achieved after covering 600 m length and the AWL is reached. So, 900 m (1500-600) at the lower part will still be left which requires pump drainage.

If the same grade is continued to the outlet than the last point of the drain bed will be 0.90 m below the AWL. This situation is not satisfactory.Selection of 0.06% and 0.05% slopes allow to cover 1000m and 1200 m respectively to reach the AWL. About 500 m & 300 m lengths are not covered respectively and these areas need pump drainage. The depth of the lowest point of drain bed in these cases will be 0.30 m & 0.15 m respectively. Pump drainage for this situation will be easier.

3. Recurring interval

For economic reason, the recurring interval or the return period of design storm may be taken as 5 years instead of a longer point. All other principles for designing the drainage system in the pumped catchment are essentially same. For pump drainage also the rainfall intensity, run-off co-efficient etc. are to be considered.

4. Determination of pumping capacity

In selecting the pump capacity the following points are to be considered (i) size of the area served (ii) amount and rate of rainfall and run-off (iii) ground water table and (iv) seepage rate.

Pump capacity can be determined as follows. Sub-surface flow should be determined from the water table gradient and permeability value. Multiplication of average water table gradient and average permeability gives the rate of sub-surface flow. In the catchment area gradient should be determined when the gravity discharge ceases. In a case study discussed later, the average difference between water tables was 0.99m.The distance between the points of water table measurements was, on average, 450m. Thus, the gradient was 0.99 / 450 = 0.0022. This gradient when multiplied by the average permeability of the soil (5.88 m/day) produced the sub-surface flow of 13mm/day. So, two pumps, each having equivalent of 1 mm/hr discharge, were chosen which were run 8 hrs. a day. Thus, these pumps could effectively cope with the sub-surface flow of 13mm/day (1mm/hr x 8hr x 2 Nos. = 16mm/day). This sub-surface flow can be scientifically determined.

To give a general guide line on the required discharge rate of pumps under different restriction levels, estimations were made for 100 ha of land having main drain at 0.1% bed grade, 1:1 side slope and with 2 m wide drain bottom. Further, the assumption was that the water level in the main drain becomes almost negligible within a period of 3 days pumping (8 hrs/day). The data are given in Table 1.

From the work done at Tocklai, tentative guide lines for appropriate channel size, required H.P. and number of pumps for catchment areas of 50 and 100 ha are given in Table 2. The data are in relation to Suprim Kirloskar Centrifugal Drainage Pump with TV2 engine, 14 HP, Head 8 m, delivery and suction hose length 8m. For pumping, the low head and higher discharge Axial-pump or Mixed flow pump should be used. However, this table serves as general guide line only. Depending upon the outfall situations either (a) only pumping, or (b) 50:50 gravity and pump discharge or (c) 67:33 gravity and pump discharge are suggested, corresponding to the discharge criteria of 30, 15 and 10 mm/day respectively.

TABLE 2. TENTATIVE SUGGESTIONS FOR PUMP DRAINAGE AT DIFFERENT SITUATIONS.

Catch ment area, ha	Out. fall m	Drai-nage sys.	Channel size Depth	Bott	Top	Pump Disch. mm/day	Pump requirement Hrs. of Pumping (single pump)	H.P. required
50 HA	Nil	100% pump	1.6	2.0	5.2	30	1500	42 (3)
	0.75	50% gravity + 33% pump	1.8	2.0	5.6	15	750	28 (2)
	1.50	67% gravity + 33% pump	2.0	2.0	6.0	10	500	28 (2)
100 HA	Nil	100% pump	1.6	4.0	7.2	30	3000	84 (6)
	0.75	50% gravity + 50% pump	1.8	4.0	7.6	15	2000	42 (3)
	1.50	67% gravity + 33% pump	2.0	3.0	7.0	10	1000	42 (3)

5. SELECTION OF PUMP

The following points are considered in selecting pumps:

(i) Type
(ii) Characteristics
(iii) Capacity
(iv) Head
(v) Number

Table 1 : Discharge rates of pumps (mm/day) under varying situation of Outlet restrictions

Depth of restriction, in m	Total discharge, to be pumped, in mm	Discharge rate for pumps to control water level in mm/day
0.30	20.0	6.66
0.50	45.0	15.00
0.70	90.0	30.00

The drainage pumps are high discharge and low head pumps. They require to handle substantial amount of sediments and trash in the water. For these either Axial-flow (propeller) or Mixed- flow pumps are commonly used. Figure 3 may be followed in selecting the appropriate pump size.

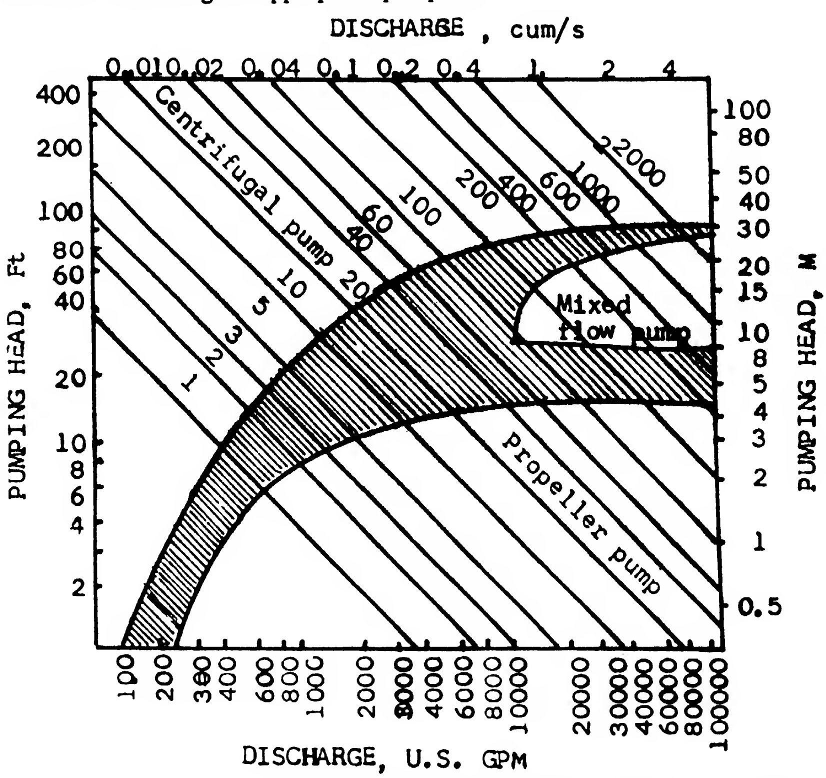


Fig. 3. Pump selection chart (U.S.S.C.S., 1973)

Axial-flow pump works well for dynamic head of 1 to 5m., speed of 450 to 1850 RPM and discharge capacities upto 6000 lit/sec. The vertical, fixed blade, single stage pump is applicable to most drainage system requirement. These pumps are simple in construction, low in cost, require no priming at head less than 3m, require a minimum amount of floor space and housing. Because of their high speed, axial-flow pumps can utilise less costly, high speed motors or engines.

Mixed-flow pumps develop flow which is partially radial and partially axial. These pumps operate more effeciently over a wide range of head i.e. 3 to 30m. These pumps can also handle silt and small trash. They permit shallower and less costly excavations and sumps but are more costly and require priming at high heads.

6. Power and drives

Electrical motors and internal combustion engines are used as power unit for drainage pump. However, electric motors are more common for their simplicity and low cost. Squirrel-case motors are more preferred than synchronous motors as they are cheap. Since the starting torques of mixed-flow or axial-flow pumps are high, capacitors should be installed with the motor to adjust the line voltage drop.

Power requirement can be determined as follows :

$$WHP = \frac{Q \times H}{76}$$

WHP = water horse power

Q = discharge rate, m^3 / sec.

H = Total pumping head, m

$$BHP = \frac{WHP}{\text{Motor efficiency} \times \text{Pump efficiency} \times \text{Transmission or drive efficiency.}}$$

BHP = Brake horse power.

With direct drive pumps the drive efficiency is 100%. The efficiency of motor and pumps are supplied by manufacturers.

7. Size of the sump

Generally the storage requirement depends on the pumping rate and frequency of cycling. In case the inflow rate is less than the pumping rate, need of cycling arises. In general, for the manually operated pumps, the number of stops and starts should not exceed two or three cycles/day. For automatically operated pumps there may be even 10-15 cycles.

The storage volume can be calculated by the following equation :

$$\frac{3600}{N} = \frac{S}{QP-Qi} + \frac{S}{Qi}$$

where, N = No. of cycles/hr.

QP = Pumping rate, m^3/sec.

Qi = Inflow rate, m^2/sec.

S = Storage volume, m^3

The reservoir should be sufficiently deep so that at the time of pumping the suction hose pipe is fully submerged. There should be at least 60 cm depth between starting and stopping levels of pump.

8. Sluice gate and retention structures

The size of sluice opening or the orifice is very important. The cross-section of a submerged type of orifice or gate can be found out from the following formula :

$$Q = CA\sqrt{2gH}$$

where Q = discharge rate, m^3/sec.

A = cross-sectional area, m^2

H = pressure head, m

C = 0.63 for submerged orifice

g = 9.81 m/Sec^2.

OTHER REQUIREMENTS OF PUMP DRAINAGE DESIGN

1. The pumping plant location is determined by :

   (a) topography
   (b) ground water condition
   (c) accessibility of power line and fuel supply roads
   (d) protection from vandalism.

   The station should be preferably located nearest the outfall and at the lowest elevation as far as practicable to increase the efficiency of pump.

2. Pumping is only done when necessary after the gravity discharge ceases.

3. There should be standby or reserve pumps to guard against breakdown or emmergency. One in three pumps is the normal provision for the standby.

PUMP DRAINAGE - A CASE STUDY

In a tea estate near Jorhat a pump drainage project was conducted on 50 ha of fairly flat land having a slope of 1m in 1000 from southern extremity towards the northern outlet. To prevent the entry of flood water in the Northern side a perimeter drain and a bund of about 90 cm height was constructed. Fig.4 shows the land contour of the area. Because of the insufficient outfall, a shallow main drain of dimensions of 1.2 m deep and 1.2 m wide was provided at the outlet at the time of taking up this drainage project. Fig.5 shows the average water level (AWL) and highest flood level (HFL) etc. of the project area.

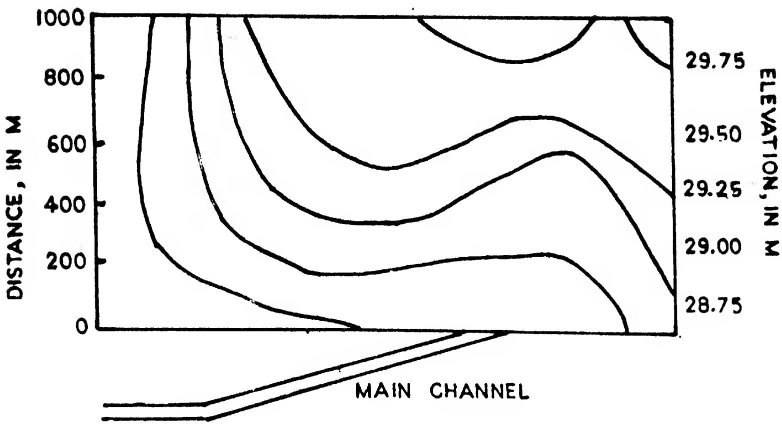


Fig.4. Land contour of pump drain area.

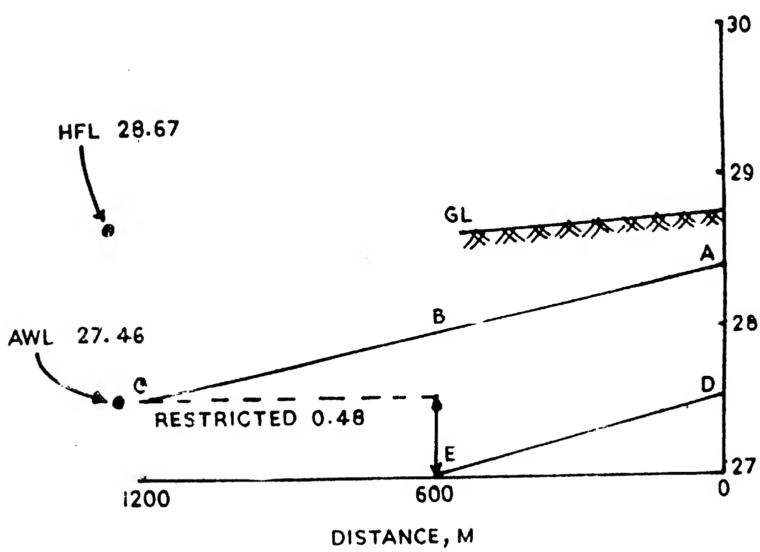
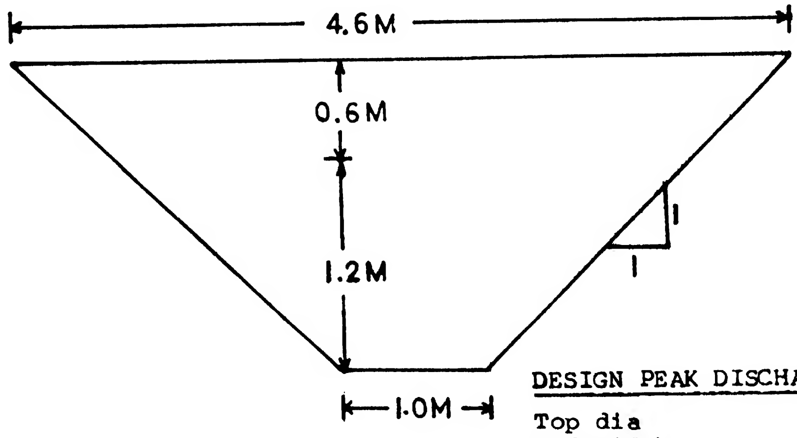


Fig.5. Outfall restriction with correct bed grade.

As there was outlet restriction the drain before starting the project was laid out at shallow depth to reach upto the river which was 600m away from the garden boundary. It was about 30 cm deep at the start of the channel and 60 cm deep at the outlet. Original grade and position of the drain is shown by ABC line. It is obvious that such shallow drain was insufficient to control the water table in field at the required depth. Considering that pumping will be resorted to , the main channel was modified. The drain was made 1.2 m deep at the starting point D and

reaching point E i.e. outlet point after covering 600m. DE line shows the modified drain bed.No doubt the drain bed went below the AWL and to take care of which sluice gate was constructed and pumping was done.At E point drain was 1.8 m deep i.e. 0.48 m lower than AWL. That is to say the outlet restriction was 0.48 m. The drain size was also increased as shown in Fig.6.



DESIGN PEAK DISCHARGE $2.22 M^3/S$

Top dia	4.6 M
Bed width	1.0 M
Total depth	1.8 M
Free board	0.6 M
Side slope	1:1
Bed slope	0.1%

Fig.6. Cross-section of modified main outlet channel.

It was observed that when the flow of the depth in the modified drain was about 0.48 m the velocity of flow was negligible confirming thereby necessity of pumping. This is shown in Fig.7.

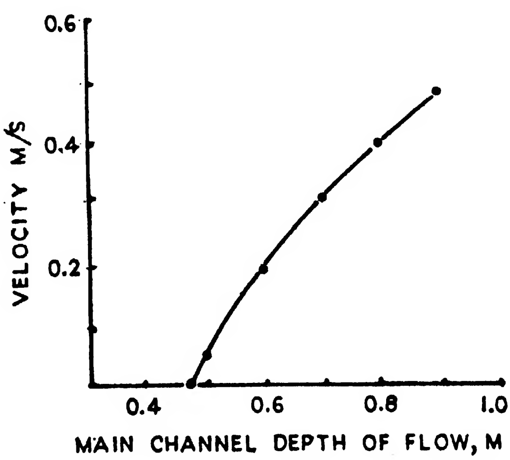


Fig.7. Relation between depth and velocity flow.

The control of W.T. between two secondary field drains as well as the average channel water level effected by both gravity and pumping discharges and the rainfall for few months are shown in Fig.8. The rainfall peaks, mid-point water table, channel water level concided very closely, thereby indicating quick response of water table to rainfall. Even at high intensity of rainfall the channel water level did not rise above 1.2 m thereby enabling control of ground water in field at 90 to 100 cm from the ground surface. Though in few occasions W.T. came up near to the surface, existance of water level in main channel at about 1.2 m depth ensured quite fast recession also.

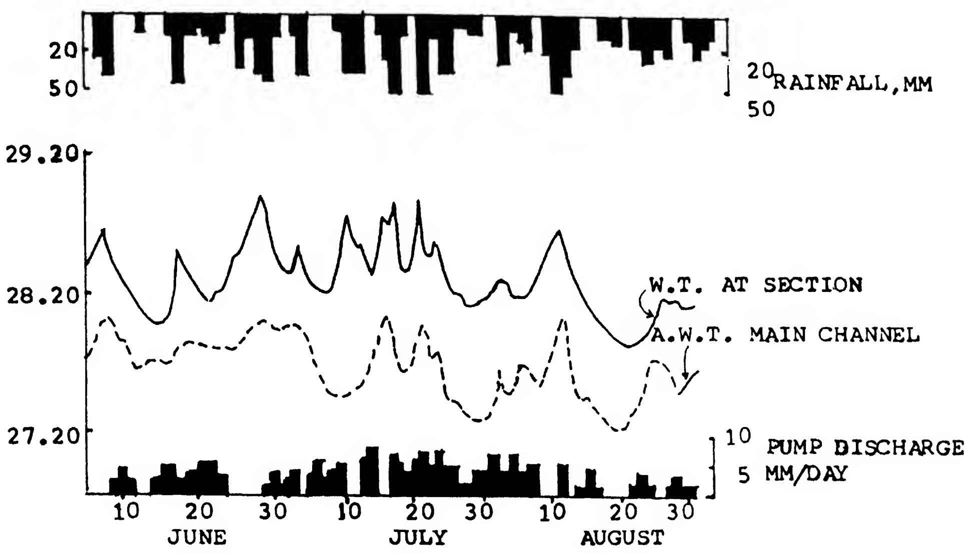


Fig.8. Effect of drainage system on water table, channel water level in monsoon months.

To make it more clear the recession of water table due to designed drainage system (both by gravity and pump discharge) is shown in Table 3. Following storms of different magnitudes the W.T. rose between 4 to 21 cm but within a period of 24 hrs. by gravity discharge alone W.T. receeded approximately between 60-70 cm.

During next 12 hours the W.T. receded only by 10-12 cm. For lowering the W.T. beyond this point pumping was resorted to and in next 12 hrs. the W.T. receeded to about 90 cm from the ground surface.

Table 3 : **Effect of the designed drainage system (gravity cum pump drainage) on the recession of ground water table mid-way between two secondary field drains.**

Event	Initial	Water table height in cm(below GL) at various hrs								
		By gravity drainage			By pump discharge					
		24	36	48	24	36	48	60	72	96
1	21	74	81	-	-	-	87	91	96	@
2	10	70	80	-	-	-	85	90	95	@
*3	13	54	66	76	-	-	-	79	84	@
4	40	79	-	-	-	87	90	92	96	@
5	4	70	-	-	-	80	86	94	@	@
6	5	66	70	82	-	-	90	90	93	102

* Intermediate rain within 24 hrs.

@ Water table increase due to rain.

The effect of improved drainage system on yield is shown in table 4. Within 3 years there was 25-55% increase in yield of mature tea. During the same period the increase of crop in young tea was about 118-232%. This is due to drainage and age factor of tea as well. The increase of average crop up to 57-63% indicates that the cost benefit ratio is favourable in case of pump drainage system.

Table 4: Effect of drainage system on yield.

	Made tea kg/ha		
	Before pump drainage*	After Pump drainage**	% increase range
Mature tea	1183	1574	25 - 55
Young tea	508	1497	118 -232
Overall	996	1570	57 - 63

* Average of five years
** Average of three years.

FUTURE OF PUMP DRAINAGE SYSTEM

The beds of the two important main recipient rivers of Assam i.e. the Brahmaputra and the Barak are rising up at a faster rate due to high order of siltation. Unless the siltation is stopped there is every chance that the gardens/sections which are now being drained marginally by gravity will suffer from acute problem of outlet restriction after some years. It is beyond doubt that if the problem is properly identified and the required area is properly segregated, a perfectly designed pump drainage system will be able to control the water table to the required depth economically.

SOIL MOISTURE MANAGEMENT IN TEA

H. GOSWAMI and D.N. SAIKIA

INTRODUCTION

Efficient use and management of water are two most critical factors responsible for increasing the productivity of tea. Vegetation and the soil on which it grows are two important components of the hydrological cycle as shown below:

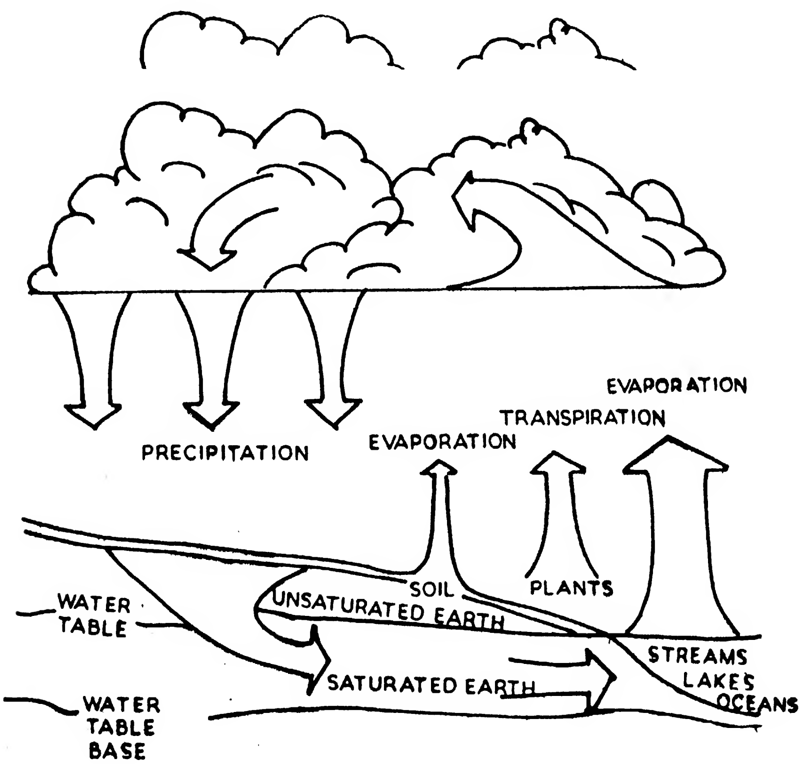


Fig. 1: Hydrological cycle

WATER BALANCE SHEET INSIDE THE SOIL

Water is added to the soil in the form of rain or irrigation and a portion of it is intercepted by tea foliage and the amount of water intercepted will depend upon the intensity of rainfall and ground cover. A portion of water will be lost to the atmosphere as evaporation and the remaining portion of water will be received by the soil. Depending upon the intensity of rainfall, slope of the land, vegetative cover, organic matter and moisture content of the soil, portion of this water will be lost as runoff and some portion will infiltrate into the soil. Again a part of the infiltrated water will be retained in the root zone of tea and the remaining portion will contribute towards building up of the water table. Some amount of this water is also lost due to deep seepage from the area.

LOSS OF WATER FROM THE SOIL

The water which remains stored in the soil is subject to two major vapour losses. Some amount of water is lost due to evaporation through capilary rise from the soil and the balance portion is lost due to transpiration through the aerial portion of the tea bushes. Fig 2 shows the water movement from the soil to plants and then to atmosphere and back to soil.

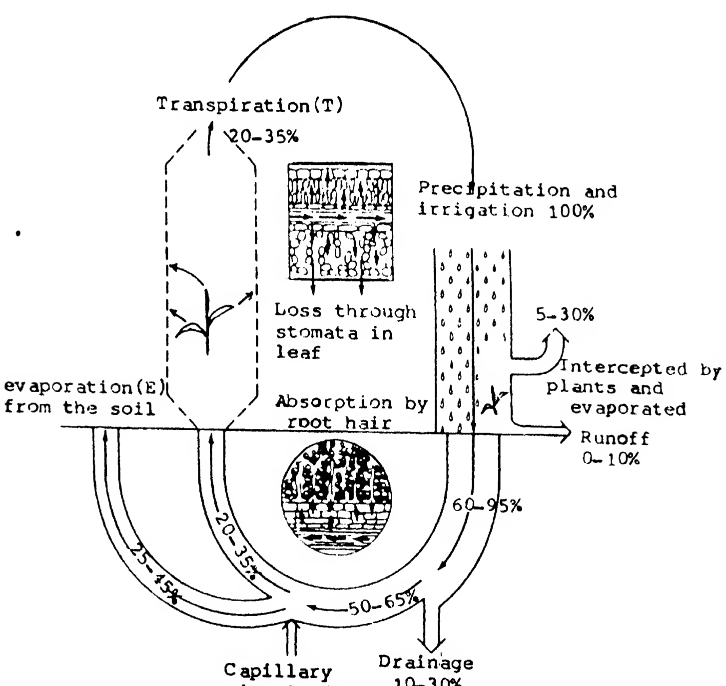


Fig 2. Water cycle from soil to atmosphere and back to soil.

SOIL WATER POTENTIAL

Energy is required for retention and movement of water in soil and the difference between the free energy of soil water and that of pure water in a standard reference state is termed soil water potential. Soil water potential decreases as water moves through the system. The moisture potential must be higher in the soil compared to the plant roots if water is to be absorbed from the soil. In the same way, water moves up the plant system in response to the difference in moisture potential.

RESISTANCE TO WATER FLOW

There are two major points of resistance to movement of water from soil to plant system- the root-soil water interface and the leaf cell-atmosphere interface. This means that two primary factors (a) the rate at which the water is supplied by the soil to the absorbing roots and (b) the rate at which the water is evaporated from the leaves, determine whether the plants are well supplied with water. Fig 3 shows the change in soil moisture potential as water moves from the soil through the plant system.

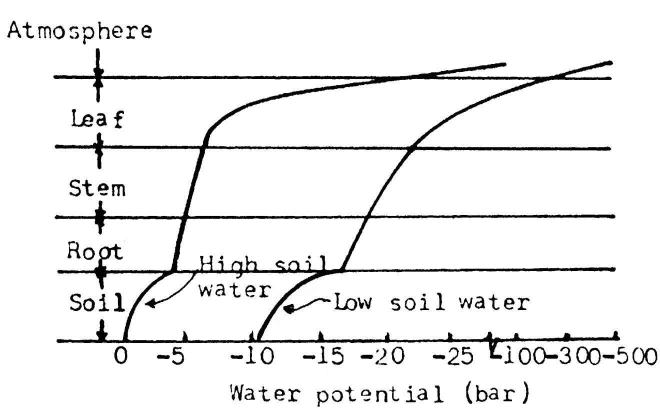


Fig 3. Change in soil moisture potential as water moves from soil through the plant system.

Fig 4. Shows the relationship between the moisture potential and soil moisture content

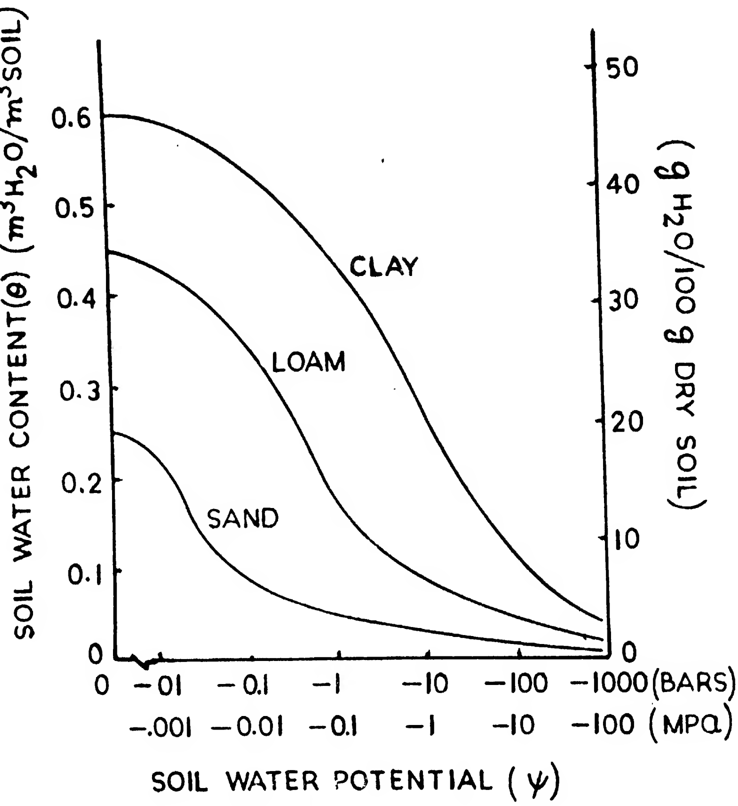


Fig 4. Soil moisture characteristics

From the above figures it can be seen that there is gradual change in potential with increased soil water and vice-versa.

MEASUREMENT OF SOIL MOISTURE

A number of methods are used to measure soil moisture and some of them which are commonly used are given below :

1. **Gravimetric**

This method permits direct measurement of the amount of water associated with a given mass of dry soil solid.

2. **Volumetric**

This is defined as the volume of water associated with a given volume of dry soil. In this method the depth of water over a given area is measured e.g. an acre foot of water or an acre inch of water. That means the volume of water needed to cover a depth of 1 feet or a depth of 1 inch over an acre of area respectively.

3. **Indirect method**

There are several indirect methods by which the soil moisture can be measured and they are **Electrical Resistance, Tension or Suction** and **Nutron Probe method.**

Electrical resistence of certain material such as Gypsum, Nylon and fibreglass is related to their water content. When such materials, suitably imbeded with electrode, are surrounded by soil they absorb water in proportion to the soil moisture content. These materials give reasonably accurate moisture reading in the range of -1 to -15 bar potential.
Water is held in the soil under some force or tension and this principle is used to measure soil water by Tensiometer method. For this field Tensiometers are used to measure the tension at which the water is held by the soil particles and the effective range is from 0 to 0.8 bar potential.

The Nutron probe moisture meter works on the ability of hydrogen atoms to reduce the speed of fast moving nutrons drastically and to scatter them.

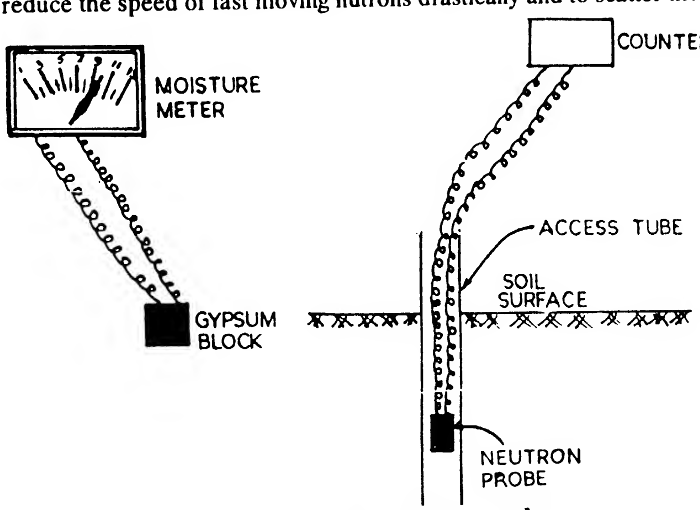


Fig 5,6 - Resistance block, Nutron probe.

MOISTURE STATUS OF SOIL

1. Saturated soil

When rain or irrigation water falls on the soil surface, it moves quickly into the soil profile depending upon the hydraulic conductivity of soil. All the micro and macropores are filled up with water and at this stage, the soil is fully saturated with water. This is the maximum retentive capacity of soil and the soil moisture potential is very high.

2. Field capacity

After 2-3 days of reaching the very high moisture potential, all the drainable water will be drained out and the macropores will become empty and the spaces will be occupied by air or gases. Only the micropores will remain filled with water which will be held tightly by the soil particles and is not influenced by gravitational force. The moisture content at this stage is called the field capacity moisture and the matric potential is -0.1 to -0.3 bar. Plant roots can very easily absorb this moisture.

3. Wilting point

With the evaporation of moisture from the soil and by transpiration, the soil moisture content is further reduced and the matric potential decreases and reaches the value of -15 bar. At this stage the moisture is so tightly held by the soil particles that the tea roots cannot absorb this moisture at all. The moisture content at this stage is called wilting co-efficient. The water at this stage is held by smallest micropores.

Table 1 shows available moisture from different types of soil.

Table 1. Available moisture for different types of soil.

Soil type	Tea Estate	F.C. %	W.P. %	Available moisture %
Sandy loam	Borbhetta	15.80	4.85	10.23
	Hunwal	14.97	5.02	9.95
	Sycotta	15.80	6.40	9.40
Silty clay loam	Ghillidary	26.47	7.75	18.72
	Koomtai	25.44	10.07	15.37
	Dirok	29.69	11.18	18.51
Poat soil	Ishabheel	51.42	25.37	26.05
	Hatikhira	49.33	21.40	27.93
	Longai	45.50	21.52	23.98

When the moisture content falls below the wilting point, the force of attraction between the moisture and the soil particles increases. This moisture is held very tightly by the soil particles and is absorbed by their colloidal surface. This moisture is held by a force which is equivalent to -31 bar.

Fig. 7 shows the volume of soil, air and water at saturated, field capacity, wilting point and hygroscopic co-efficient.

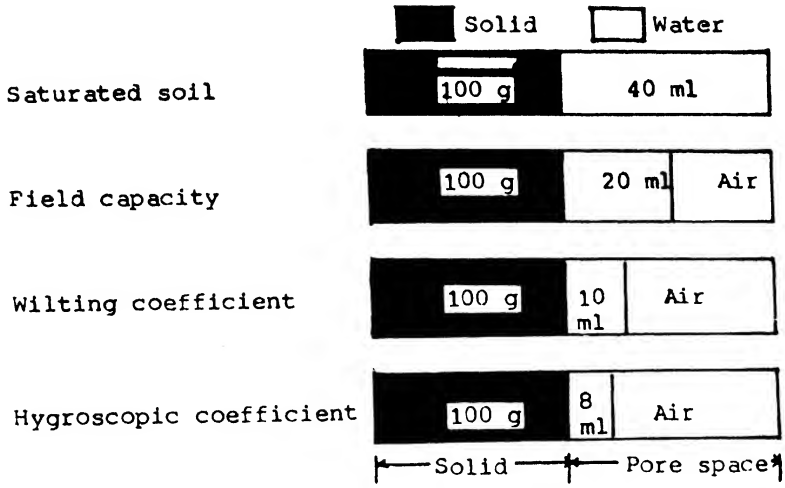


Fig.7. Proportion of soil, water and air at different moisture status of soil.

There is a well established relationship between moisture retention and its subsequent use by plant. Gravitational water is of little use and may be harmful. On the other hand, the soil moisture retained in the soil between the field capacity (-0.1 to -0.3 bar) and the wilting co-efficient (-15 bar) is said to be usable by plant and can be termed as available water. Water held at potential lower than -15 bar is unavailable to most of the plants.

Under normal circumstances for optimum plant growth the soil moisture content should be maintained near field capacity with a potential of -1 bar or higher.

SOIL MOISTURE LOSS

Moisture from the soil is lost by direct evaporation and through transpiration from the aerial parts of plants and this two losses together is called evapotranspiration (ET) losses. This is influenced by atmospheric vapour pressure, temperature, wind velocity and soil moisture content. ET losses during the dry period for different tea growing areas of Assam is presented in table 2.

Table 2. ET losses during the months October-April in different regions.

	MONTH						
Region	Oct	Nov	Dec	Jan	Feb	Mar	Apr
South Bank	117	66	37	30	40	79	114
North Bank	125	65	41	30	42	96	122
Cachar	135	79	42	35	51	96	135
Docars	105	65	43	36	45	90	128

SOIL MOISTURE MANAGEMENT

Evapotranspirational losses are influenced by certain soil and crop management practices and the efficient use of water by plants is affected by these management practices. Soil moisture retention can be increased by the following factors:

1. **Consolidation**

   A good ground cover is essential for conservation of moisture in tea. Therefore, the vacancies should be infilled to consolidate the tea areas to achieve better ground cover.

2. **Green/Cover crop and Mulching**

   Judicious use of green crop together with heavy mulching in young tea areas especially on the south-western aspect of slopy land will help in conserving soil moisture which will be available to tea plants. On slopes, using mulch in strips across the direction of the slope will reduce soil erosion drastically.

3. **Shade trees**

   It is a well established fact that shade trees help in conserving soil moisture tremendously. Therefore, efforts must be made to improve shade status of tea areas, where required. A good stand of shade trees also adds 4000-5000 kg of organic matter per ha in the form of leaf, twig falls annually.

4. **Tillage**

The method of minimum tillage should be practiced to conserve soil moisture, top soil, nutrients and organic matter in the soil.

5. **Hard pan**

Presence of a hard pan or an impervious layer in sub-soil is detrimental for infiltration or flow of water into the soil. Sub-soiling is recommended where soil is heavy or hard pan exists.

6. **Drainage**

With good sub-soil drainage it is possible to increase the usable soil moisture content in the root zone of tea. In water logged soils all the pores are filled with water and the soil become deficient in oxygen. By a system of good drainage it is possible to supply enough oxygen to root zone and to release carbondioxide to the atmosphere.

7. **Irrigation**

Soil moisture deficit can be made up through irrigation. However, for efficient use of irrigation water, a good sub-soil drainage system is most important.

SOIL CHEMISTRY UNDER WATERLOGGED CONDITIONS

K.K.GOHAIN

INTRODUCTION

Plant roots and soil micro-organisms utilise oxygen from the soil air and give off carbon-di-oxide. A continuous supply of oxygen is needed for this process and if this supply becomes insufficient as in waterlogged soils then the plant growth will be limited due to insufficient supply of nutrients. Some toxic substances such as ethylene, methane, hydrogen sulphide, cyanide, butyric acid etc. accumulate under waterlogged condition which impair the growth of plants.

Submerging a soil brings about a number of electrochemical changes in soil, viz (i) a decrease in redox-potential, (ii) an increase in soil pH, (iii) cation and.anion exchange reactions, (iv) absorptions and desorptions of lons.

SOIL REDUCTION

The most important chemical difference beween a waterlogged soil and a well drained aerated soil is that the former is in a reduced state (i.e. lack of oxygen). Although a thin, brown oxidised layer is observed at the surface, waterlogged soil is grey, blue-greenish in colour due to the reduction of ferric iron to ferrous iron and has a low redox potential. The redox potential of a soil provides a useful measure of its oxidation reduction status which affect the growth of plants. A waterlogged soil has reduced counterparts of Nitrate, Sulphate, Manganese, Ferric iron and Carbon-di-oxide : Ammonium, Hydrogen sulphide, Ferrous iron and Methane. Reduction in the soil is a consequence of anaerobic respiration by soil bacteria. This reducing condition in the soil affects many inorganic and biological processes and as such has an important impact on plant growth. In simple terms, a positive Redox potential indicates oxidising condition of the soil whereas a negative indicates the reverse i.e. reducing condition. In general, the redox potential of waterlogged soil lies in the range of + 600 milli volts to -200 milli voilts. A specific sequence of reactions take place under waterlogged conditions which can be divided into two stages as shown in table 1

Table 1: Microbial metabolism in waterlogged soil

Main reactions	Redox potential (E_h)	
FIRST STAGE		
Oxygen disappearance & carbon di-oxide production	+ 600	+ 500mv
Nitrate reduction & Nitrite formation	+ 600	+ 500mv
Manganous (Mn) formation	+ 600	+ 500 mv
Ferrous (Fe) formation	+ 500	+ 300 mv
SECOND STATE		
Sulphate reduction & sulphide formation	0.0	- 170 mv
Hydrogen formation	- 150	-220 mv
Methane or Marsh-gas formation	-130	-170 mv

Thus, from Table 1, it is seen that anaerobiosis begins with the disappearance of Oxygen and Carbon-di-oxide gas formation. The nitrate is microbiologically reduced to nitrite which may be toxic to plant roots and through this process of denitrification nitrate is finally reduced to Nitrogen gas and in this way Nitrogen is lost from the soil (Gaseous loss through denitrification).

Manganese and Ferric iron reduce to manganous and ferrous iron associated with slight drop in the redox potential of soil.
The redox-potential is reduced substantially in the second stage as a result of the reduction of sulphate to sulphide such as hydrogen sulphide gas which is toxic to plant. Hydrogen and Methane are also formed with further reduction in redox potential.

The soils with high percentage of organic matter have lower redox potentials due to the fact that organic matter favours the growth and metabolism of anaerobic microoganisms. Fig. 1 shows the range of redox-potentials usually found in well-drained aerated soil and in waterlogged soil.

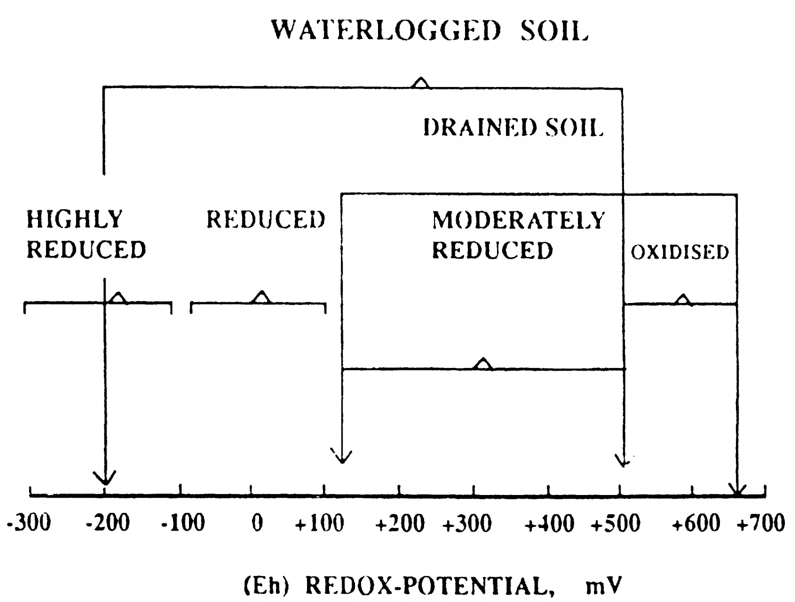


Fig.1. Redox-potential in well-drained and Water-Logged soil

1. **Qualitative tests for sulphide (H_2S)formation**

Sulphide injury in the root system revealed clearly by the following qualitative tests:

(i) Foul Odour of H_2Sgas when the roots are smeared with N/10 Hcl.

(ii) Change in colour of the root system from black to a reddish brown when exposed to atmosphere due probably to the oxidation of sulphide compounds.

THE PH OF WATERLOGGED SOILS;

After submergence of an aerobic soil the pH decreases during the first few days and then rises asymptotically to a value ranging between 6.7-7.2 in a few weeks time. The overall effect of submergence of tea soils is to increase the pH which is due to the reduction process under waterlogged conditions.

The rise in pH due to waterlogging may be due to the change in redox potential of Fe^{+3}/Fe^{+2} and Mn^{4+}/Mn^{2+} systems whereas decreasing trend after 56 days (Table 1a) of submergence may be due to the production of CO2-gas or organic acid. Reduction of Eh due to change of Fe^{3+} to Fe^{2+} and M^{4+} to M^{2+} increased the pH of the submerged soil.

Table 1 A : Effect of soil submergence on p H

Soil No.	pH of the soil after submergence (days)									
	0	8	16	24	32	40	48	56	64	72
1	4.90	5.30	5.35	6.00	6.00	6.50	6.50	6.43	6.30	5.80
2	5.20	5.35	5.70	6.00	6.10	6.00	6.20	6.20	5.90	5.60

Mean room temper.=32°C

Soil pH increases with lowering of temperature due to decreased ionisation in the soil extract (Table 1B)

Table 1B: Soil p H as affected by lowering of temperature (sumbmerged soil).

Soil pH at (.C)	
At 30 C	At 18 C
5.52	5.71
5.00	5.05
5.43	5.58
5.35	5.50
6.25	6.45

Table 2: Reduction Reactions in soil.

$$3Fe\,(OH)_3 + H^+ + e^- = Fe_3(OH)_8 + H20$$

$$No_3^-\,(aq) + 6H^+\ aq + 5e = \frac{1}{2}\,N2\,(gas) + 3H20$$

$$No_3^-\ aq + 2H^+\ aq + 2e = No_2^-(aq) + H_2O$$

$$So_4^{--}\ aq + 10H^+aq + 8e = H_2S\ aq + 4H2O$$

$$Co_2(gas) + 8H^+ + aq + 8e^- = CH_4(gas) + 2H_2O$$

$$HPO_4^-\ aq + 10H^+ + aq + 8e^- = PH_3(GAS) + 4H2O$$

(b) Nitrogen loss from waterlogged soil:
Nitrogen may be lost from a waterlogged soil in four ways, viz.
(i) denitrification (ii) leaching losses of nitrate and ammonia
(iii) ammonia volatilisation (iv) run-off.

(i) Denitrification:
Oxidised forms of nitrogen, nitrite and nitrate, can be used by certain facultative anaerobic micro-organisms and reduced to nitrogen gas. This is an anaerobic bacterial process called denitrification. It results in a decreased fertiliser use efficiency and contributes a substantial portion of the atmospheric nitrogen oxides, which is a potential threat to the environment through the formation of nitric acid. The rate of denitrification is known to increases with increase in pH, nitrate concentration and the availability of reductants in the soil. Fig.2 shows how the added nitrogenous fertiliser is lost through denitrification. Ammonium-N applied to the oxidised soil surface is nitrified and then leaches down into the reduced sub-surface layer, where it is denitrified and lost from the soil.

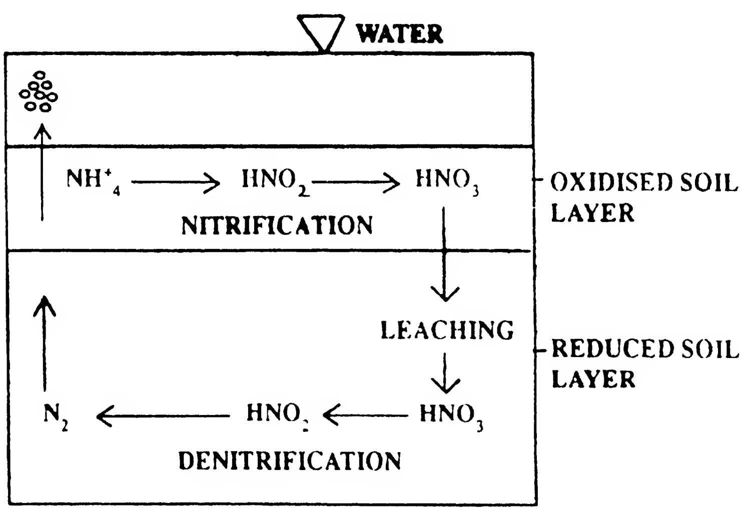


Fig.2. Denitrification of N-fertiliser In soil

The decrease in pH after a few days submergenc is probably due to the increased accumulation of carbon doixide in the soil produced by respiration of aerobic bacteria. The subsequent increase in pH of acid soils is due to the soil reduction. As all important reduction reactions involve the consumption of hydrogen ion and thereby increasing the pH.

Organic Matter Decomposition
The decomposition of organic matter in a waterlogged soil is slower as compared to well-drained aerated counterpart. The end products are also different. As anaerobic bacteria operate at a much lower energy level than aerobic bacteria, both decomposition and assimilation are much slower in waterlogged soil than in aerobic soils. In a normal well-drained soil the end products are carbon dioxide, nitrate, sulphate and resistant residues (humus) whereas in a waterlogged soil, they are carbon-di-oxide, hydrogen, Methane, Ammonia, hydrigen sulphide etc.

Nitrogen:
Under waterlogged condition, the nitrogen supply comes from three sources (i) Ammonium N present when the soil is waterlogged (ii) Nitrogen mineralised from soil orgainic matter and plant residue under waterlogged conditions and (iii) Nitrogen added as a fertiliser.

Nitrate and Nitrite nitrogen present in the soil at the time of submergenc are usually lost quite rapidly through denitrification.

(a) Mineralisation of nitrogen:

The moneralisation of organic nitrogen in waterlogged soils stops at the ammonia stage because of the lack of oxygen to carry the process of nitrification via nitrite to nitrate. Thus, ammonia accumulates in anaerobic and waterlogged soil. Mineralisation of organic nitrogen to ammonium stage is very rapid in waterlogged soil as compared to the well-aerated soil. Mineralised -N in waterlogged soil is in the from of ammonium iron only but in a well-aerated soil, it is in the three forms because of the presence of oxygen.

Ammonia production in waterlogged soils follows roughly a asymptotic curve and the kinetics of ammonia release can be described by:

$\text{Log } (A-Y) = \log A - Ct$
where : A = mean maximum NH_4-N concentration
Y= actual concentration " t" days after submergence
C= a parameter depending on the soil.

(ii) Ammonia Volatilisation:
This loss under waterlogged condition is not considered as important one except in specialised cases where a high ammonia concentration occurs in conjunction with high pH, high temperature and low C.E.C. value of soil.

(iii) Leaching of nitrate and ammonia nitrogen and run-off:
Nitrate present in the root zone of a soil, which is waterlogged at the begining of the season, is almost invariably lost by denitrification or is leached out of the rootzone, if not absorbed by the plant roots. Nitrate can also be lost by surface run-off. Ammonium nitrogen on the other hand, is much less subject to leaching from soil than nitrate-N because of its adsorption on the cation exchange complex. But, this is not so in a waterlogged soil because of the following reasons:

(i) Ammonium N does not accumulate in a well-drained soil as much as it does in a waterlogged soil.

(ii) Ferrous iron and Manganous irons produced as a result of soil reduction in a waterlogged soil, displace NH4-N from the exchange complex to the soil solution where it is more subject to removal.

Phosphorus

Phosphorus is present in organic and inorganic forms in soils. The inorganic form is more important under waterlogged conditions. Al-P and Fe-P predominate in acid tea soils and they release phosphates with the increase of soil pH. With the soil reduction, both water soluble and available phosphate increases because of the facts that : 1) Fe-P and Al-P hydrolyses, 2) Reduction of
Ferric Iron to Ferrous iron Liberates adsorbed and chemically bonded-P.

Another possible process of increase in the availability of phosphorus has been explained by the following reaction which occur under highly reduced (waterlogged) condition:

$$Fe_3(PO_4)_2 + 3H_2S = 3FeS + 2H_3PO_4$$

The reducing condition caused by waterlogging activates the forms of phosphate that are normally insoluble in well-drained soil. Ferric-P is reduced to the more soluble ferrous forms.

Effect of waterlogging on replaceable bases:

A significant increase in replaceable ammonia, magnessium and manganese takes place when a soil is kept waterlogged for sufficiently long time but for calcium, a significant depression was observed. No significant change was observed with replaceable potassium due to soil submergence.

Erosion under waterlogged condition:

Under waterlogged condition when the soil pores are filled with water, permeability is greatly hampered and most of the rain water, instead of percolating through, accumulates on the surface and moves along the natural slope causing serious surface wash and loss of fertile top soil.

The estimated loss of soil and nutrients under different gradients is shown in Table 3.

Table 3. Soil and nutrient loss due to runoff.

Land slope, %	Soil loss, kg/ ha	Loss of nutrients kg/ ha Nitrogen	Phosphate	Potash
6.0	1,345	3.3	1.8	9.0
3.0	636	1.3	0.8	3.7
2.5	616	1.4	0.8	4.0
1.0	541	1.4	0.3	4.0

Rainfall intensity-20.6mm /hr.

It is seen from table 3 that with a moderate intensity of rainfall, considerable soil and nutrient losses can occur. Further, the nutrient loss from plots with 6% slope are more than double of the quantities lost in all other slopes under study. A marked reduction in nutrient loss was observed under mulched conditions.

Gaseous loss of nitrogen through denitrification in waterlogged soil:

Nitrogen is the major input in tea. When applied to the soil it is converted to No_3 -which is taken up by the plant. Gaseous loss of N through denitrification is greatly encouraged by poor drainage and lack of oxygen. The micro-organisms responsible for denitrification are anaerobic that thrive under poor drainage and waterlogged conditions. The amount of No_3-N found at various levels of oxygen supply in the soil is shown in Table 4.

Table 4 Relationship between Nitrate-N and Oxygen.

Soil O_2	NO_3-N (% of added N)
20.0	46
11.o	43
4.5	38
2.1	28
1.0	21
0.4	2

Loss by chemical reduction in acid soil condition

Tea soils are acidic. Nitrite in slightly acid environment in low pH soils evolve gaseous-Nitrogen when brought in contact with ammonium salts or simple amines, such as urea. The following reaction is suggestive of what may occur to urea:

$$2HNO_2 + CO(NH_2)_2 = CO_2 + 3H_2O + 2N_2$$

Studies carried out so far suggest that about 10-15% of the applied nitrogen is lost through gasification. In general, these losses are unavoidable, but some control can be exerted by improving ground cover and by providing adequate drainage and soil tilth.

SUMMARY

Prolonged waterlogging is detrimental to tea. Therefore, a properly designed drainage system is essential to prevent the ill-effects of waterlogging.
Tea plants under waterlogged condition are frequently attacked by pests and diseases like red spider, red rust, black rot etc. As such spraying of suitable acaricides and fungicides is essential to save the plants from the attack of such pest and diseases.

ECONOMICS OF DRAINAGE

R. C. AWASTHI

INTRODUCTION

In order to achieve 1000 million kg tea by 2000 A.D., drainage improvement is considered to play a major role in future also. More than 1 lakh hectares area in N.E. India requires improved drainage system to obtain the optimum crop from the existing tea areas.

Considering the importance of the subject, the Agro Economics Department of Tocklai took up a study during 1982 to 1985 to find out the economics of drainage. The study is based upon the data collected from six different sites covering the total area of about 1000 hectares under scientifically designed drainage system.

The projects were located in the estates where problem of stagnation in productivity was noticed.

The project selected had a large area under improved drainage system covering between 25 hectares to 500 hectares.

There was no major change adopted as far as cultural practices were concerned. A pruning cycle of 4 year was adopted in the concerned section.

The project areas and the control plots had the same average yield per hectare before taking up the project. With time, whereas the yield of the project area having improved drainage system increased from average 1656 kg/ha to 2134 kg/ha in 3 years period, the increase in control plots was found negligible during the same period.

COST OF DRAINAGE

The cost data were collected from the estates where the projects were taken up. This included capital cost of survey, digging drains, construction of culverts etc. and the Recurring cost of maintenance of drainage. The interest @ 12.5% on capital cost and 17% on the maintenance cost have also been included.

The distribution of cost on different items of drainage are given in Table 1.

Table 1. **Cost of Improvement of drainage system per hectare for 3 year period (Rs.).**

Capital Cost	**1st Yr.**	**2nd Yr.**	**3rd Yr.**	**Total**
1. Cost of Survey	216	--	--	216
2. Cost of Digging Drains	3504	--	--	3504
3. Cost of construction of Culvert etc.	990	--	--	990
Total Capital Cost	**4710**	--	--	**4710**
Recurring Cost				
4. Maintenance Cost	224	352	416	992
Total	**4934**	**352**	**416**	**5702**

INCREASE IN YIELD

The yield figures were supplied by the estates together with other details like rainfall, pruning percentage, use of inputs like fertilizers, weedicides, pesticides etc. in the project areas and control plots. The present exercise is based upon the yield data only.

Table 2. **Increase in Yield from improved drainage projects (kg/ha).**

Project No.	Area (ha)	Pre-Drainage Year yield (kg/ha)	Increase in Yield kg/ha 1 Yr.	2 Yr.	3 Yr.	Total
A	113	1460	364	366	555	1285
B	26	2293	627	319	--	946
C	48	2698	829	851	--	1680
D	138	1223	204	516	526	1246
E	555	1968	220	426	--	646
F	114	1303	265	448	478	1191
	994	1765	279	452	520	992

CONTRIBUTION

The return is computed by taking the amount of contribution. The formula for contribution is Average selling Price minus varible cost or Fixed Cost plus margin of profit. In the present exercise the average selling price is taken @ Rs.45/- per kg and average cost is taken @ Rs.35/- per kg, Rs.20/- per kg fixed cost and Rs.15/- as variable cost. Thus the contribution is - Rs.45/- - Rs.15/- = Rs.30/- per kg.

SOME DETAILS ABOUT THE PROJECTS

1. **Project No. C**

A drainage project covering about 48 ha of land under tea was started. The soil of the project area belongs to medium texture i.e. Sandy loam type. The area suffered from high ground water table throughout the rainy season and was also prone to surface floods due to backflow from river.

A network of drainage system was designed having 105 cm deep subsidiary drains at 30 m spacing in gridiron pattern.

The scientifically designed drainage system could effectively control the ground water table below the desired 90 cm level throughout the period of observation, whereas the conventional drained area, the water table remained in the root zone all throughout the period as was found close to 40 cm to the ground surface.

Drainage system prevailed prior to project implemtation.

Old drainage system :

i) Lateral drains	: Depth	-- 75 cm
	Spacing	-- 50 m
	Length	-- 400 m/ha
ii) Sub-main drains	: Depth	-- 90 cm
	Spacing	-- 50 m
	Length	-- 400 m/ha
iii) Main drains		-- N .

Improved drainage system

i) Lateral Drains	: Depth	-- 105 cm
	Spacing	-- 30 m
	Length	-- 335 m per ha
	System	-- Grid iron
ii) Sub-main Drain	: Depth	-- 120 cm
	Spacing	-- 120 m
	Length	-- 88 m per ha
iii) Main Drain	: Depth	-- 150 to 200 cm
	only one main drain	

Table 3. **Cost Benefit Analysis (per ha).**

Period	Cost of drainage Rs.	Int. Rs.	Total cost Rs.	Return		Net cumulative gain Rs.
				Yield kg/ha	Contribution Rs.	
1st year	5,774	722	6,496	829	24,870	18,374
2nd year	600	102	702	851	25,530	45,499

Cost Benefit Ratio = 1 : 6.32

* Interest on Balance @ Rs. 12.50% (included in Income)

2. Project No. D

Another project was taken up covering 138 ha of land under old mature teas. The soil belonged to silty loam texture. The sub-soil was denser and compacted. The major source of excess water causing waterlogging was surface seepage flow combined with local rainfall.

The improved drainage system could very effectively control the water table below the optimum rootzone depth i.e. 90 cm throughout the rain storm.

Drainage system prevailed prior to project implemtation.

Old drainage system :

i) Lateral drains	: Depth	-- 45 cm
	Spacing	-- 12 m
	Length	-- 1500 m/ha
ii) Sub-main drains	: Depth	-- 75 cm
	Spacing	-- 40 m
	Length	-- 500 m/ha
iii) Main drains	: Depth	-- 100 cm

Improved drainage system

i) Lateral Drains	: Depth	-- 105 cm
	Spacing	-- 25 m
	Length	-- 400 m per ha
	System	-- Grid iron
ii) Sub-main Drain	: Depth	-- 120 cm
	Spacing	-- 100 m
	Length	-- 200 m per ha
iii) Main Drain	: Depth	-- 150 cm
	only one main drain	

Table 4. Cost Benefit Analysis (per ha).

Period	Cost of drainage Rs.	Int. Rs.	Total cost Rs.	Return		Net cumulative gain Rs.
				Yield kg/ha	Contribution Rs.	
1st year	4,310	538	4,848	204	6,120	1,272
2nd year	400	68	468	516	15,480	15,171
3rd year	400	68	468	526	15,780	32,379

Cost Benefit Ratio = 1 : 5.59

* Interest on Balance @ Rs. 12.50% (included in Income)

SUMMARY AND CONCLUSION

The economic evaluation of the projects reflect the variations in cost due to difference in soil structure and rainfall pattern etc. and also in yield due to potentiality of the bushes to achieve different degree of improvement in yield.

The additional benefits due to better utilisation of inputs like fertilizers and reduced expenses on weeds and pests have not been taken into account here for estimating total benefits.

It is quite obvious that the improved drainage will play a significant role in increasing the yield of mature teas in N.E. India. In addition, the adoption of scientific drainage system in the extension and replanted areas in future will also provide a major boost to the productivity of young tea areas of North East India.

APPENDIX

TABLE 1 : TABLE SHOWING VERTICAL INTERVAL & HORIZONTAL DISTANCE IN METERS BETWEEN DRAINS FOR VARYING SOIL TYPES AND SLOPES WHERE RAINFALL IS OVER 4400 MM PER YEAR

Calculations based on formula vertical interval in meters with adjustments for soil texture as indicated in the table = (percentage slope) / 4+1.75

Percent Slope	COARSE TEXTURE (Sand & Loamy Sands) V.I. Adjustment + 20 to 12%		MODERATELY COURSE TEXTURE V.I. Adjustment + 12 to 4%		MEDIUM TEXTURE (Loams & Silt Loams) V.I. Adjustment + 4 to – 4%		MODERATELY FINE TEXTURE (Clay Loams & Silty Clay Loams) V.I. Adjustment – 4 to – 12%		FINE TEXTURE (Silty Clay & Clay) V.I. Adjustment – 12 to – 20%	
4%	1.0 0.9	24.4-23.5	0.9-0.9	23.5-21.9	0.9-0.8	21.9-20.1	0.8-0.7	19.8-18.6	0.7-0.7	18.6-16.8
5%	1.0-0.9	21.9-20.4	1.0-0.9	20.4-18.9	1.0-0.9	18.9-17.7	0.9-0.8	17.7-16.2	0.8-0.7	16.2-14.6
6%	1.2-1.1	19.8-18.6	1.1-1.0	18.6-17.1	1.0-0.9	17.1-15.8	0.9-0.9	15.8-14.6	0.9-0.8	14.0-13.1
7%	1.3-1.2	18.3-17.1	1.2-1.1	17.1-15.8	1.1-1.0	15.8-14.6	1.0-0.9	14.6-13.4	0.9-0.9	13.4-12.2
8%	1.4-1.3	17.1-16.2	1.3-1.2	16.2-14.9	1.2-1.1	14.9-13.7	1.1-1.0	13.7-12.5	1.0-0.9	12.5-11.6
9%	1.5-1.4	16.2-15.2	1.4-1.3	15.2-14.0	1.3-1.2	14.0-13.1	1.0-1.1	13.7-11.9	1.1-1.0	11.9-11.0
10%	1.6-1.5	15.5-14.6	1.3-1.3	14.6-13.4	1.3-1.2	13.4-12.5	1.2-1.1	12.5-11.3	1.1-1.0	11.3-10.6
12%	1.7-1.6	14.6-13.4	1.6-1.5	13.4-12.5	1.5-1.4	12.5-11.6	1.4-1.3	11.6-10.7	1.4-1.2	10.7-9.8
16%	2.1-2.0	13.1-12.2	2.0-1.8	12.2-11.3	1.8-1.7	11.3-10.7	1.7-1.6	10.7-9.8	1.6-1.4	9.8-8.8
20%	2.5-2.3	12.5-11.6	2.3-2.1	11.6-10.7	2.1-2.0	10.7-9.8	2.0-1.8	9.8-9.1	1.8-1.6	9.1-8.5
24%	2.8-1.1	11.9-11.0	2.7-2.5	11.0-10.4	2.5-2.3	10.4-9.4	2.3-2.1	9.4-8.5	2.1-1.9	8.5-7.9
28%	3.2-2.8	11.6-10.7	3.0-2.8	10.7-10.1	2.8-2.6	10.1-9.1	2.6-2.3	9.1-8.5	2.3-2.1	8.5-7.6
30%	3.6-3.3	11.3-10.4	3.3-3.1	10.4 -9.8	3.1-2.9	9.8-8.8	2.9-2.6	8.8-8.2	2.6-2.4	8.2-7.3
36%	3.9-3.7	11.0-10.1	3.7-3.4	10.1-9.4	3.4-3.1	9.4-8.8	3.1-2.9	8.8-7.9	2.9-2.6	7.9-7.3
40%	4.3-4.0	10.7-10.1	4.0-3.7	10.1-9.4	3.7-3.4	9.4-8.5	3.4-3.1	8.5-7.9	3.1-2.9	7.9-7.3
48%	5.0-4.7	10.4-9.8	4.7-4.4	9.8-9.1	4.4-4.0	9.1-8.5	4.0-3.7	8.5-7.6	3.8-3.4	7.6-7.0

V.I. = Vertical Interval

TABLE 2 : TABLE SHOWING VERTICAL INTERVAL & HORIZONTAL DISTANCE IN METERS BETWEEN DRAINS FOR VARYING SOIL TYPES AND SLOPES WHERE RAINFALL IS BETWEEN 2500 TO 4400 MM PER YEAR

Calculations based on formula vertical interval in meters = (percentage slope) / 4+2 with adjustments for soil texture as indicated in the Colums

Percent Slope	COARSE TEXTURE (Sand & Loamy Sands) V.I. Adjustment + 20 to 12%		MODERATELY COURSE TEXTURE V.I. Adjustment + 12 to 4%		MEDIUM TEXTURE (Loams & Silt Loams) V.I. Adjustment + 4 to – 4%		MODERATELY FINE TEXTURE (Clay Loams & Silty Clay Loams) V.I. Adjustment – 4 to – 12%		FINE TEXTURE (Silty Clay & Clay) V.I. Adjustment – 12 to – 20%	
4%	1.1-1.0	27.4-25.6	1.0-0.9	25.6-23.8	0.9-0.9	23.8-21.9	0.9-0.8	21.9-20.1	0.8-0.7	20.1-6.8
5%	1.2-1.1	23.8-22.3	1.1-1.0	22.3-20.7	1.0-0.9	20.7-18.9	0.9-0.9	18.9-17.4	0.9-0.8	17.4-14.6
6%	1.3-1.2	21.3-19.8	1.2-1.1	19.8-18.3	1.1-1.0	18.6-17.1	1.0-0.9	17.1-15.5	0.9-0.9	15.5-13.1
7%	1.4-1.3	19.5-18.3	1.3-1.2	18.3-17.1	1.2-1.1	17.1-15.8	1.1-1.0	15.8-14.3	1.0-0.9	14.3-12.2
8%	1.5-1.4	18.3-17.1	1.4-1.3	17.1-15.8	1.3-1.2	15.8-14.6	1.2-1.1	14.6-13.4	1.1-1.0	13.4-11.6
9%	1.6-1.5	17.4-16.2	1.5-1.3	16.2-14.9	1.3-1.2	14.9-13.7	1.2-1.1	13.7-12.8	1.1-1.0	12.0-11.0
10%	1.6-1.5	16.5-15.2	1.5-1.4	15.2-14.3	1.4-1.3	14.3-13.1	1.3-1.2	13.1-12.2	1.2-1.1	12.2-10.4
12%	1.8-1.7	15.2-14.3	1.7-1.6	13.7-13.1	1.6-1.5	13.1-12.2	1.5-1.3	12.2-11.3	1.3-1.2	11.3-9.8
16%	2.2-2.0	13.7-12.8	2.0-1.9	12.8-11.9	1.9-1.8	11.9-11.0	1.8-1.6	11.0-10.1	1.6-1.5	10.1-8.8
20%	2.6-2.4	12.8-11.9	2.4-2.2	11.9-11.0	2.2-2.0	11.0-10.4	2.0-1.9	10.4-9.4	1.9-1.7	9.4-8.5
24%	2.9-2.7	12.2-11.3	2.7-2.5	11.3-10.7	2.5-2.3	10.7-9.8	2.3-2.1	9.8-8.8	2.1-2.0	8.8-7.9
28%	3.3-3.1	11.9-11.0	3.1-2.9	11.0-10.1	2.9-2.6	10.1-9.4	2.6-2.4	9.4-8.5	2.4-2.2	8.5-7.6
30%	3.7-3.4	11.6-10.7	3.4-3.2	10.7-0.1	3.2-2.9	10.1-9.1	2.9-2.7	9.1-8.5	2.7-2.4	8.2-7.3
36%	4.0-3.7	11.3-10.4	3.7-3.5	10.4-9.4	3.5-3.2	9.8-8.8	3.2-3.0	8.8-8.2	3.0-2.7	8.2-7.3
40%	4.4-4.1	11.0-10.4	4.1-3.8	10.4-9.4	3.8-3.5	9.4-8.5	3.5-3.2	8.5-7.9	3.2-2.9	7.9-7.3
48%	5.1-4.8	10.7-10.1	4.8-4.5	10.1-9.1	4.5.-4.1	9.1-8.5	4.1-3.7	8.5-7.9	3.7-3.4	7.9-7.0

V.I. = Vertical Interval
H.D. = Horizontal distance

TABLE 3 : TABLE SHOWING VERTICAL INTERVAL & HORIZONTAL DISTANCE IN METERS BETWEEN DRAINS FOR VARYING SOIL TYPES AND SLOPES WHERE RAINFALL IS BELOW 2500 PER YEAR

Calculations based on formula vertical interval in meters = (percentage slope) /4+3 with adjustments for soil texture as indicated in the table.

Percent Slope	COARSE TEXTURE (Sand & Loamy Sands) V.I. Adjustment + 20 to 12%		MODERATELY COURSE TEXTURE V.I. Adjustment + 12 to 4%		MEDIUM TEXTURE (Loams & Silt Loams) V.I. Adjustment + 4 to – 4%		MODERATELY FINE TEXTURE (Clay Loams & Silty Clay Loams) V.I. Adjustment – 4 to – 12%		FINE TEXTURE (Silty Clay & Clay) V.I. Adjustment – 12 to – 20%	
4%	1.5-1.4	36.6-34.1	1.4-1.3	34.1-31.7	1.3-1.2	31.7-29.3	1.2-1.1	29.3-26.8	1.1-1.0	26.8-24.4
5%	1.6-1.5	31.1-29.0	1.5-1.3	29.0-26.8	1.3-1.2	26.8-25.0	1.2-1.1	25.0-22.9	1.1-1.0	22.9-20.7
6%	1.6-1.5	27.4-25.6	1.5-1.4	25.6-23.8	1.5-1.3	23.8-21.9	1.3-1.2	21.9-20.1	1.2-1.1	20.1-18.3
7%	1.7-1.6	24.7-23.2	1.6-1.5	23.2-21.6	1.6-1.4	21.6-19.8	1.4-1.3	19.8-18.3	1.3-1.2	18.3-16.5
8%	1.8-1.7	22.9-0.2	1.7-1.6	21.3-19.8	1.7-1.5	19.8-18.3	1.5-1.3	18.3-16.8	1.3-1.2	16.8-15.2
9%	1.9-1.8	21.3-19.8	1.8-1.7	19.8-18.6	1.7-1.5	18.6-17.1	1.5-1.4	17.1-15.5	1.4-1.3	15.5-14.3
10%	2.0-1.9	20.1-18.9	1.9-1.7	18.9-17.4	1.9-1.7	17.4-16.8	1.7-1.5	16.8-14.6	1.5-1.3	14.6-13.4
12%	2.2-2.0	18.3-17.1	2.0-1.9	17.1-15.8	2.4-1.8	15.8-14.6	1.8-1.6	14.6-13.4	1.6-1.5	13.4-12.2
16%	2.6-2.4	16.2-14.9	2.4-2.2	14.9-14.0	2.5-2.0	14.0-12.8	2.0-1.9	12.8-11.9	1.9-1.7	11.9-10.7
20%	2.9-2.7	14.6-13.7	2.7-2.5	13.7-12.8	2.9-2.3	12.8-11.6	2.3-2.2	11.6-10.7	2.1-2.0	10.7-9.8
24%	3.3-3.1	13.7-12.8	3.1-2.9	12.8-11.9	3.2-2.6	11.9-11.0	2.6-2.4	11.0-10.1	2.4-2.2	10.1-9.1
28%	3.7-3.4	13.1-12.2	3.4-3.2	12.2-11.3	3.5-2.9	11.3-10.4	2.9-2.7	10.4-9.4	2.7-2.4	9.4-8.8
32%	4.0-3.7	12.5-11.9	3.7-3.5	11.9-11.0	3.8-3.2	11.0-10.7	3.2-3.0	10.1-9.1	3.0-2.7	9.1-8.5
36%	4.4-4.1	12.2-11.3	4.1-3.8	11.3-10.7	4.1-3.5	10.7-9.8	3.5-3.2	9.8-8.8	3.2-2.9	8.8-8.2
40%	5.1-4.5	11.9-11.0	4.5-4.1	11.0-10.4	4.8-3.8	4.4-9.4	3.8-3.5	9.4-8.8	3.5-3.2	8.8-7.9
48%	5.5-5.1	11.6-10.7	5.1-4.8	10.7-10.1	4.5-4.4	10.1-9.1	4.4-4.0	9.1-8.5	4.0-3.7	8.5-7.6

V.I. = Vertical Interval
H.D. = Horizontal distance